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16. Abstract

The FAR23 Loads program provides a procedure for calculating the loads on an airplane according to the Code of Federal Regulations, Title 14—Aeronautics and Space, Chapter I—Federal Aviation Administration, Subchapter C—Aircraft, Part 23—Airworthiness Standards: Normal, Utility, Aerobatics, and Commuter Category Airplanes, Subpart C—Structures.

Most of the detail flight loads are developed from the flight envelopes specified in FARs 23.333 and 23.345. At every point specified in the flight envelope, the airplane is balanced by a tail load reacting to the specified liner normal acceleration and the aerodynamic lift, drag, and moment about the center of gravity. The data needed to make these balancing calculations consists of (1) weight and center of gravity, (2) aerodynamic surface geometry, (3) structural speeds, and (4) aerodynamic coefficients. After the balanced load data are developed, the critical structural loads are determined for each component. For the critical conditions, the air loads, inertial loads, and net loads are calculated. Aileron, flap, tab, engine mount, landing, and one engine out loads are also calculated. Landing loads are calculated from the landing gear geometry, landing load factor, weight, and center of gravity data.

The FAR23 Loads program was developed by Aero Science Software to calculate the loads on an airplane using methods acceptable to the FAA. The program includes 20 modules that are each self-contained programs designed for a specific application.

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PREFACE

This User's Guide for the FAR23 Loads program was developed by the University of Dayton Research Institute for use by the Federal Aviation Administration (FAA). The FAR23 Loads computer program was developed by Hal C. McMaster, under contract to the University of Dayton Research Institute, as part of the FAA Grant No. 93-G-051 entitled "Research Leading to the Development of Commuter Airlines Structural Integrity Management." The program monitor for the FAA is Mr. Thomas DeFiore of the FAA William J. Hughes Technical Center at Atlantic City International Airport, New Jersey, and the Program Technical Advisor is Mr. Terence Barnes of the FAA Aircraft Certification Office in Seattle, Washington. Dr. Joseph Gallagher is the principal investigator for the University of Dayton. Mr. Daniel Tipps and Dr. Alan Berens are co-principal investigators. Ms. Peggy Miedlar was the lead engineer for this project.

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LIST OF SYMBOLS AND ABBREVIATIONS

A_t	absolute angle at the tail
AR_w	aspect ratio of the wing
a	speed of sound
b	wing span
cg	center of gravity
C_D	drag coefficient
C_L	lift coefficient
$C_{L\text{-}ail}$	lift coefficient of the aileron
$C_{L\text{-}f}$	lift coefficient of the flap
$C_{L\text{-}w}$	lift coefficient of the wing
C_M	pitching moment coefficient
D_x	drag load
d_y	number of increments to divide the surface into
EAS	equivalent air speed
h	altitude
i_t	incidence of tail, angle from waterline to zero lift line of tail
i_w	incidence of wing, angle from waterline to zero lift line of wing
I_{ZZ}	moment of inertia about vertical axis (z-axis)
K	ratio of empty weight to takeoff weight
$KEAS$	knots, equivalent airspeed
L	load
L_{ail}	load on the aileron
L_{flap}	load on flap
L_t	load at the 25% chord of the tail
M_C	Mach number at the design cruise speed V_C
M_D	Mach number at the design dive speed V_D
MAC	mean aerodynamic chord (mean geometric chord)
n	load factor (positive or negative)
n_x	horizontal load factor
n_z	normal load factor
P	pressure
P_{LE}	pressure at the leading edge
q	dynamic pressure ($= \frac{1}{2}\rho V^2$)
RN	Reynolds number
S_{ail}	surface area of the aileron
$S_{ail\text{-}aft}$	surface area of aileron aft of the hinge line
$S_{ail\text{-}fwd}$	surface area of aileron forward of the hinge line
S_{flap}	surface area of flap

EXECUTIVE SUMMARY

The FAR23 Loads program is designed to calculate loads for airplanes that will be certified under FAR Part 23 requirements. The FAR23 Loads program was developed for the FAA by Hal C. McMaster of Aero Science Software. This manual is a User's Guide for the program FAR23 Loads and is intended as a guide for running the individual modules that make up FAR23 Loads. The theoretical development of FAR23 Loads is explained in the manual "FAR23 Loads" by Hal C. McMaster.

1. INTRODUCTION.

1.1 ABOUT FAR23 LOADS.

The FAR23 Loads program was developed by Aero Science Software to calculate the loads on an airplane using methods acceptable to the FAA. The program includes 20 modules that are each self-contained programs designed for a specific application.

Most of the detailed flight loads are developed from the flight envelopes specified in the federal requirements FARs 23.333 and 23.345. At every point specified in the flight envelope, the airplane is balanced by a tail load reacting to the specified linear normal acceleration and the aerodynamic lift, drag, and moment about the center of gravity. The data needed to make these balancing calculations consist of (1) weight and center of gravity, (2) aerodynamic surface geometry, (3) structural speeds, and (4) aerodynamic coefficients. These data are developed by modules in the FAR23 Loads program.

After the data needed to calculate the balancing loads are developed, the critical structural loads are determined for each component. For the critical conditions, the air loads, inertia loads, and net loads are calculated. Aileron, flap, tab, engine mount, landing, and one engine out loads are also calculated.

The landing loads are calculated from the landing gear geometry, landing load factor, weight, and center of gravity data.

1.2 FEDERAL REGULATIONS.

The program FAR23 Loads provides a procedure for calculating the loads on an airplane according to the Code of Federal Regulations, Title 14—Aeronautics and Space, Chapter I—Federal Aviation Administration, Subchapter C—Aircraft, Part 23—Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes, Subpart C—Structures. This is referred to as FAR Part 23. The regulations through Amendment 42 have been included in the FAR23 Loads program.

1.3 USING THE MANUAL.

This manual is a guide to run the FAR23 Loads program and is intended to be a supplement to reference 1. Reference 1 provides the theoretical development of the equations used in the computer program.

Section 2 tells the user how to install the program and run FAR23 Loads. Section 2 also includes general information on how to run the individual modules, how to enter data, how to save the results, and how to print the output.

Sections 3 through 22 are each devoted to a separate module of the FAR23 Loads program and are organized according to the order that the modules appear in the main menu. Each section has up to five sections: description, FAR 23 regulations, running the module, output, and graphics.

2. GETTING STARTED.

2.1 SYSTEM REQUIREMENTS.

The program FAR23 Loads is designed to run on a personal computer. The minimum system requirements are:

- a DOS-compatible personal computer with at least an 80286 processor,
- minimum 640K RAM,
- 580K of free conventional memory,
- MS-DOS version 3.1 or higher,
- a hard drive, not bigger than 2GB, with at least 720K of free space,
- a 3.5-inch floppy disk drive, and
- a mouse is recommended, but not required.

For best performance, it is recommended that you exit Windows before running FAR23 Loads. If you are running Windows, most of the modules in FAR23 Loads can be run by opening a DOS window. Some of the modules require a full-window DOS window.

2.2 FAR23 LOADS DISKS.

The FAR23 Loads program is contained on nine disks. Five of the disks are the installation disks for the FAR23 Loads program, two data disks contain the data files and output for the sample airplanes, one disk contains the plotting modules FAR23 Plot and related files, and the final disk includes the Qbasic programs for the modules in FAR23 Loads. Table 2.1 lists the files included in the FAR23 Loads program disks and provides a description of each file.

2.3 INSTALLING FAR23 LOADS.

The FAR23 Loads program must be installed on your computer using the DOS *setup* program provided. To do this, follow these steps.

- Insert the disk labeled "Disk 1 Setup" into your disk drive. This drive is assumed to be the "a" drive in these instructions.

- From DOS: At the DOS prompt, type the following: `a:setup`.

- From Windows 3.1: Go to the File menu of the Program Manager and select Run. At the command, type: `a:setup`, then press `Enter`.

- From Windows 95: Go to Start, select Run, then type: `a:setup` and press `Enter`.

- You will be asked to "Specify the source directory containing the FAR23 Loads Program files." This is "a:\".

- Next you will be asked to "Specify destination directory for FAR23 Loads program files." Enter the full path of the directory where you want the files, such as C:\FAR23LDS. If the directory does not exist, it will be created.

- Follow the on-screen instructions to continue the installation. You will be prompted to insert disks 2, 3, 4, and 5.

- The input and output data files for two sample airplanes are included on the data disks. If you want to copy this data to your hard drive, you should use a separate subdirectory for each set of data. Note that some of the files names are the same for the two airplanes, and if you copy both sets of data to the same directory, you will overwrite some data files.

- Insert the disk labeled "Data Disk 1" into your disk drive. From the DOS prompt, type XCOPY A:*.* C:\FAR23LDS\DATA1*.*. This command assumes that you installed the FAR23 Loads programs in the directory C:\FAR23LDS. The XCOPY command will create the directory DATA1 if it does not exist.

- Insert the disk labeled "Data Disk 2" into your disk drive. From the DOS prompt, type XCOPY A:*.* C:\FAR23LDS\DATA2*.*. This command assumes that you installed the FAR23 Loads programs in the directory C:\FAR23LDS.

- If you are running from Windows 3.1, you can create an icon for the program. First, create a program group, then create a program item. To do this, from Program Manager, select the File menu. Select the New option, then choose Program Group. Enter the following information, then click OK:

Description:	FAR23 Loads
Group File:	(you can leave this blank)

  To create the program item, from Program Manager, select the File menu. Select the New option, then choose Program Item. Enter the following information and click OK:

Description:	FAR23 Loads
Command Line:	C:\FAR23LDS\FAR23LDS.EXE
Working Directory:	C:\FAR23LDS

The installation of the plotting programs is described later in this section.

To install the Qbasic programs, copy the files from the disk to a directory on your hard drive. You can run these programs by typing the filename at the DOS prompt.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will allow the output file to be saved to a file. *Print Output* allows you to perform the calculations and print the output file. *Return to Main Menu* exits the module and returns to the FAR23 Loads Main Menu.

The *Open* command is used to retrieve a previously created and saved file. When you select *Open*, a window appears as shown in figure 2.2. There are three main areas of the window. At the top, the File Name appears. Below this, the current path name is given, and below that are two boxes. The box on the left lists the files in the directory, and the box on the right is the directory tree. Each box has a scroll bar so that you can move through the list. To select a file, move the cursor to the file so that it is highlighted, then click the mouse button. The file should appear in the File Name box. Use the "OK" button when you find the file you want to open, or "Cancel" to close this window without opening a file. Note that when you select "OK", the file that appears in the File Name box will be opened.

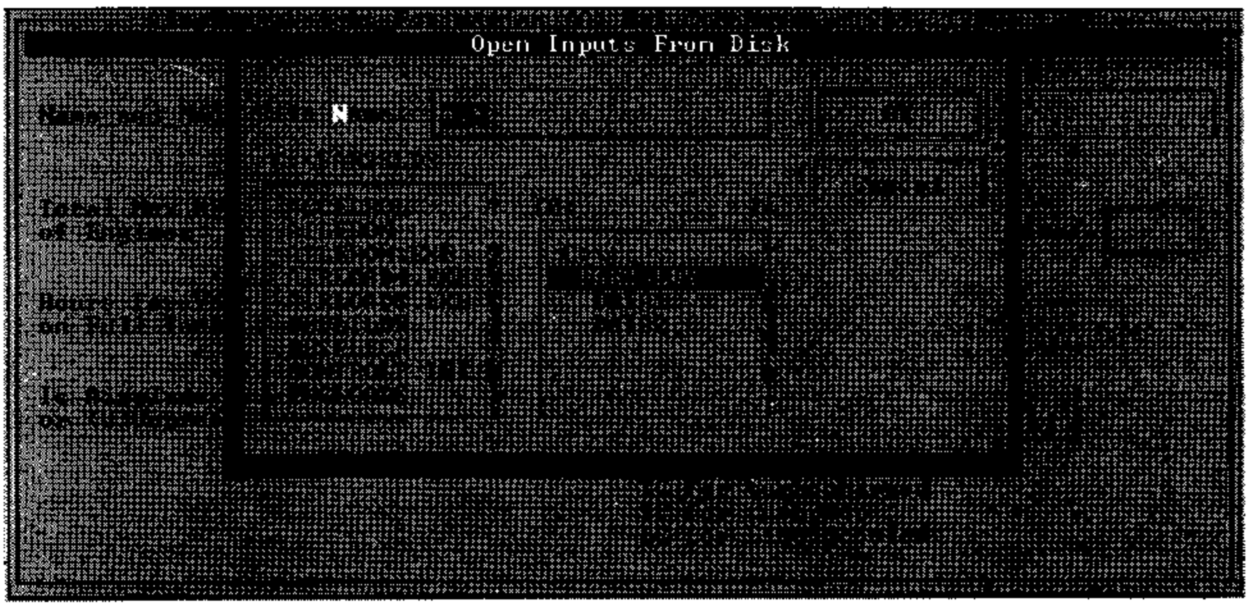

FIGURE 2.2 FAR23 LOADS WINDOW FOR OPENING FILES

In the file name field, you can specify the file that you want. Enter the name or *.*, then press enter. In the left box, the list of files will appear. To change directories, in the right box, select the appropriate directory. When you change directories, the file list in the left box will be updated.

To search for all files, enter *.* for the file name and press Enter. Now all files in the directory will appear Note that if you enter "*", only files without a file name extension will appear. For example, if you enter "*", AILERON.INP will not appear, but BBFLTLDR will. If you use "*.*", then both files will appear. For the sample airplanes, there are files without file extensions.

For the modules with more than one input window, you can run the analysis from any window. Be sure you have filled in the data for all input windows before doing the analysis.

The output from some of the modules will be used as input for other modules. Table 2.2 lists each module, the section that describes it, the module that the input comes from, and the modules that use the output.

TABLE 2.2 SUMMARY OF MODULES IN THE FAR23 LOADS PROGRAM

MODULE	SECTION	INPUT FROM	OUTPUT TO
WESTIMA	3		WTONECG, WTENV
WTONECG	4	WTESTIMA	FLTLOADS, SELECT, LANDLOAD, ONENGOUT
WTENV	5	WTESTIMA	FLTLOADS
WINGGEOM	6		STRSPEED, AIRLOADS, AIRLOAD4, FLTLOADS, SELECT, ONENGOUT
STRSPEED	7	WINGGEOM	MACHLIM, FLTLOADS, AILERON, FLAPLOAD
MACHLIM	8	STRSPEED	
AIRLOADS	9	WINGGEOM, SELECT	SELECT, NETLOADS
AIRLOAD4	10	WINGGEOM, SELECT	SELECT, NETLOADS
FLTLOADS	11	WTONECG, WTENV, WINGGEOM STRSPEED, AIRLOADS, AIRLOAD4	SELECT, WINGINER
SELECT	12	WTONECG, WINGGEOM, FLTLOADS	AIRLOADS, AIRLOAD4, WINGINER, TAILDIST
AILERON	13	STRSPEED	
FLAPLOAD	14	STRSPEED	
WINGINER	15	FLTLOADS, SELECT	NETLOADS
NETLOADS	16	AIRLOADS, AIRLOAD4, WINGINER	
ENGLOADS	17		
LANDLOAD	18	WTONECG, LGFACTOR	
LGFACTOR	19		LANDLOAD
TAILDIST	20	SELECT	
TABLOADS	21		
ONENGOUT	22	WINGGEOM, WTONECG	

memory is required to run all modules. If your computer does not have enough memory available, the module will not run. To check your memory, at the DOS prompt type

```
C:\ MEM
```

If you have problems running the modules from the main menu, try running them as stand-alone programs. To do this, at the DOS prompt, type

```
C:\ program   password
```

where `program` is the name of the module, and the password is `8191995`.

2.7 FAR23 PLOT PROGRAMS.

The graphics programs FARPLOT and GEOMPLOT are stand-alone programs for plotting data and drawing airplane geometries. These programs read the output data from FAR23 Loads programs and graph it using a variety of options. The plotting programs are designed so that the user can customize the graphs for use in reports.

GEOMPLOT is used to plot the geometric surfaces using the data from WINGGEOM (section 6). FARPLOT is used to plot all other results. Table 2.3 shows the data that can be plotted.

In this manual, the plotting programs are discussed in each section if there are results that can be plotted. Detailed instructions for using the plotting programs are included in the appendix of reference 1.

2.7.1 Installing FAR23 Plot.

To install the plotting programs, follow these steps:

- Insert the disk labeled "FAR23 Plot" into your disk drive. This drive is assumed to be the "a" drive in these instructions.
- DOS prompt: At the DOS prompt, type the following: `a:setup`.
- Windows 3.1: Go to File menu option in the Program Manager and select the "RUN" option. At the command line field, type `a:setup`, then press `Enter`.
- Windows 95: Go to Start, select Run, then type `a:setup` at the prompt.
- You will be asked to specify the source directory containing files. This is "a:\".
- Next you will be asked to specify the destination directory. Enter the full path of the directory where you want the files. If the directory does not exist, it will be created.

3. WEIGHT ESTIMATION.

3.1 WTESTIMA DESCRIPTION.

There are three weight estimation modules in the FAR23 Loads program. The first module, WTESTIMA, estimates the weight of the airplane and its major components. The other two modules, WTONECG and WTENV, are discussed in sections 4 and 5, respectively.

To estimate the weight of the airplane and components, the following information is required:

- number of engines,
- total horse power,
- type of engine (4-cycle reciprocal, 2-cycle reciprocal, turbocharged, turboprop, liquid-cooled),
- hours of endurance at cruise speed,
- number of seats,
- total baggage weight, and
- whether the cabin is pressurized.

The takeoff weight is a function of the useful load, and the useful load consists of three items: the weights of passengers, baggage, and fuel. The passenger weight is assumed to be 170 pounds per seat. The fuel weight is calculated for the chosen endurance time at cruise altitude and is based on the total horsepower and engine type.

Statistically, the ratio of empty weight to takeoff weight has been found to be 0.62. The empty weight (W_{empty}) is calculated as the takeoff weight minus the useful load, $W_{empty}=W_{TO}- W_{use}$. By knowing the useful load (W_{use}), the takeoff weight (W_{TO}) can be determined as

$$W_{TO} = \frac{W_{use}}{(1-K)}$$

where K is 0.62 plus a factor to adjust for the engine type and pressurized cabins. For an unpressurized 4-cycle reciprocal single engine, the adjustment factor is zero. Table 3-1 lists the adjustments to K for various engine types.

3.2 RUNNING WTESTIMA.

To run WTESTIMA, select the module from the main menu window. You will see the main input window as shown in figure 3.1.

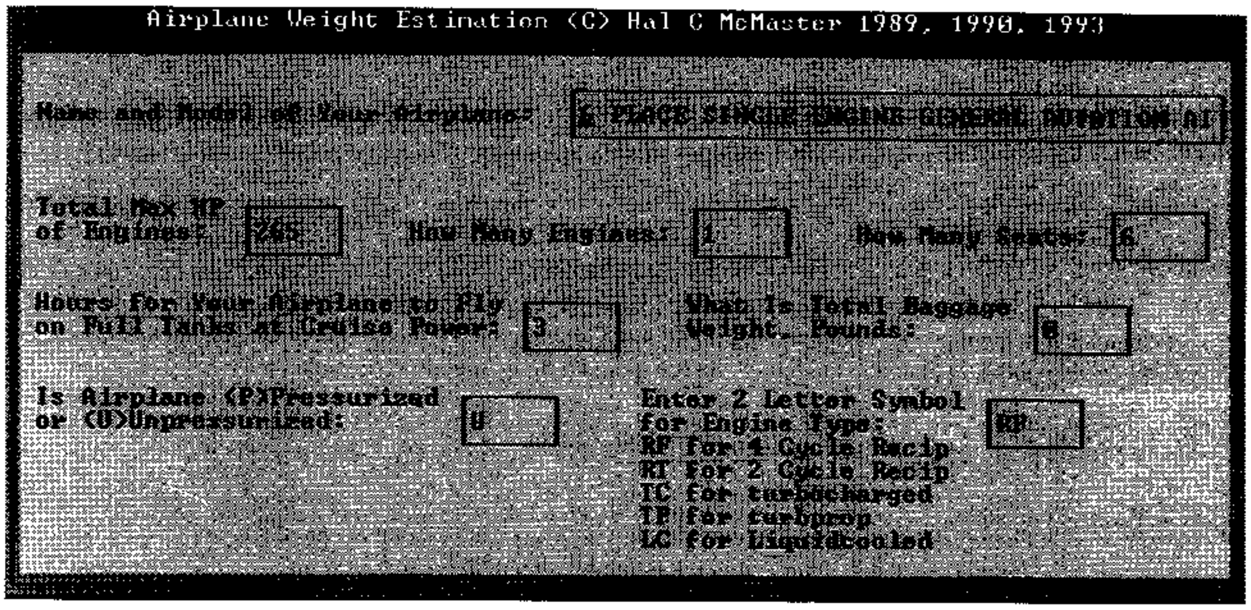

FIGURE 3.1 WTESTIMA INPUT WINDOW

3.2.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes the three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a printer or a file. *Return to Main Menu* exits from WTESTIMA and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program, where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input that is required includes the title, maximum continuous horsepower, number of engines, number of seats, endurance at cruise power, total baggage weight, if the cabin is pressurized, and the type of engine.

4. WEIGHT AND INERTIA.

4.1 WTONECG DESCRIPTION.

WTONECG calculates the weight, center of gravity, and inertia of the airplane for any specific loading configuration. These calculations are done at the four c.g. locations defining the weight structural limits diagram. These c.g. locations are the aft gross weight, the forward gross weight, the most forward reduced weight, and the minimum weight. On an airplane with retractable landing gear, it is usually necessary to account for the shift in c.g. due to retraction of the gear with a second set of four loading conditions.

The weight limits are defined in FAR 23.25. The maximum weight must not be less than the empty weight plus 170 pounds for each seat for normal and commuter categories (or 190 pounds for utility and acrobatic category airplanes) plus oil at full capacity and a half hour of fuel at maximum continuous power. Also, the maximum weight must not be less than the empty weight plus minimum crew and full tank capacity of fuel and oil.

The minimum weight is not more than the empty weight (including unusable fuel, full oil, and fluids) plus the minimum crew (usually the pilot) and a half hour of fuel at maximum continuous power. For turbojet powered airplanes, the required fuel is 5 percent of the total fuel capacity.

The location of the weight components can be established from the three-view drawing or inboard profile drawing. The weight can be obtained from the component manufacturer, from actual weighing of the part, by calculation from drawing dimensions and material density, or from WTESTIMA (see section 3).

The input data that are required are the coordinates, weight and moment of inertia for each of the components of the airplane, and useful loads for the loading. The inertia of small components may be neglected with no appreciable effect on the total inertia of the airplane.

The component data is entered in the weight database. This is the same database file use by WTENV. The database file can be created and modified in either WTONECG or WTENV.

4.2 DEVELOPING THE WEIGHT DATABASE.

The database contains the component weight data and the location dimensions for all components that you wish to consider. The same database is used for both WTENV and WTONECG.

The default value for the maximum number of components in the database is 100, although the user may change this value. The database is divided into three sections: empty weight items, minimum weight items, and discretionary items. Fifty percent of the items are considered empty weight items, ten percent are minimum weight items, and forty percent are discretionary items. The type of item is indicated by the item number. If you use the default value of 100 items, then items 1 through 50 are empty weight items, items 51 through 60 are minimum weight items, and

4.3.1.2 Minimum Weight.

The minimum weight (the lowest weight at which compliance with each applicable requirement of Part 23 is shown) must be established so that it is not more than the sum of

a. the empty weight determined under FAR 23.29,

b. the weight of the required minimum crew (assuming a weight of 170 pounds for each crewmember), and

c. the weight of

   (1) (for turbojet powered airplanes), 5 percent of the total fuel capacity of that particular fuel tank arrangement under investigation and

   (2) (for other airplanes), the fuel necessary for one-half hour of operation at maximum continuous power.

4.4 RUNNING WTONECG.

To run WTONECG, select WTONECG from the main menu window. The first WTONECG window is shown in figure 4.1. You must open an existing file before you can enter data.

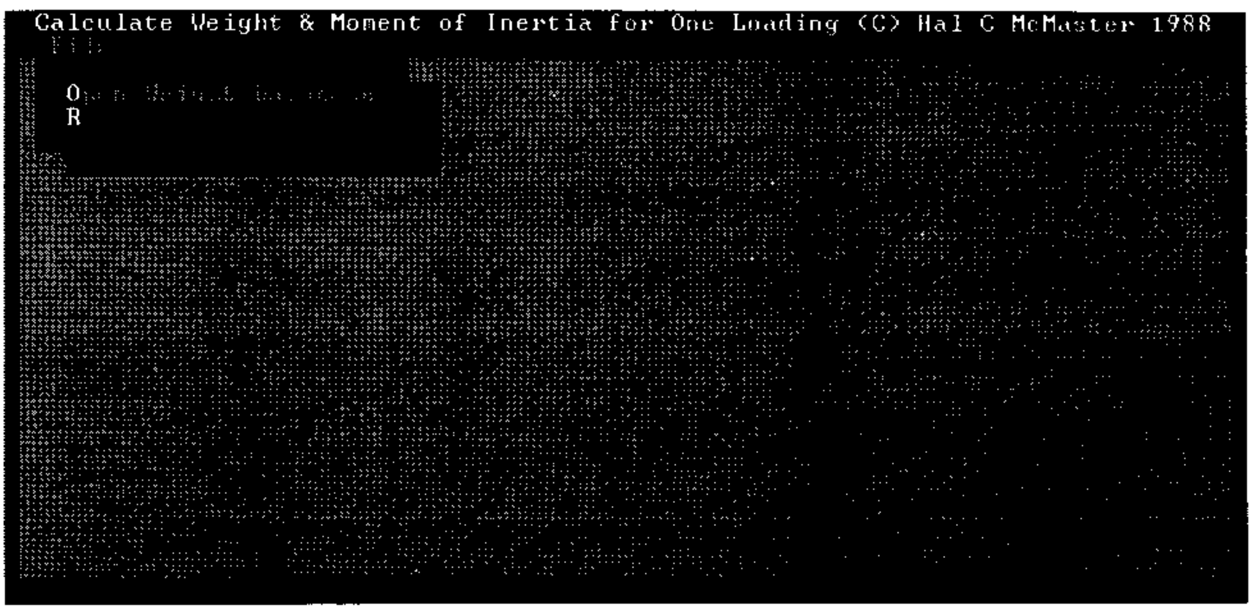

FIGURE 4.1 WTONECG FIRST WINDOW

4.4.1 First Window.

The first window is displayed when the module starts; it includes four menu options: File, Notepad, Size, and Color. When the WTONECG module is first opened, the File menu includes

the database, scroll through the database to that item. Then select Edit and select *Delete Current Item.* The current item is immediately deleted—you will not be asked to confirm the deletion!

The Size option sets the number of items in the database. Figure 4.3 shows this option. The default value is 100. The Color option allows you to change the color scheme displayed on your window.

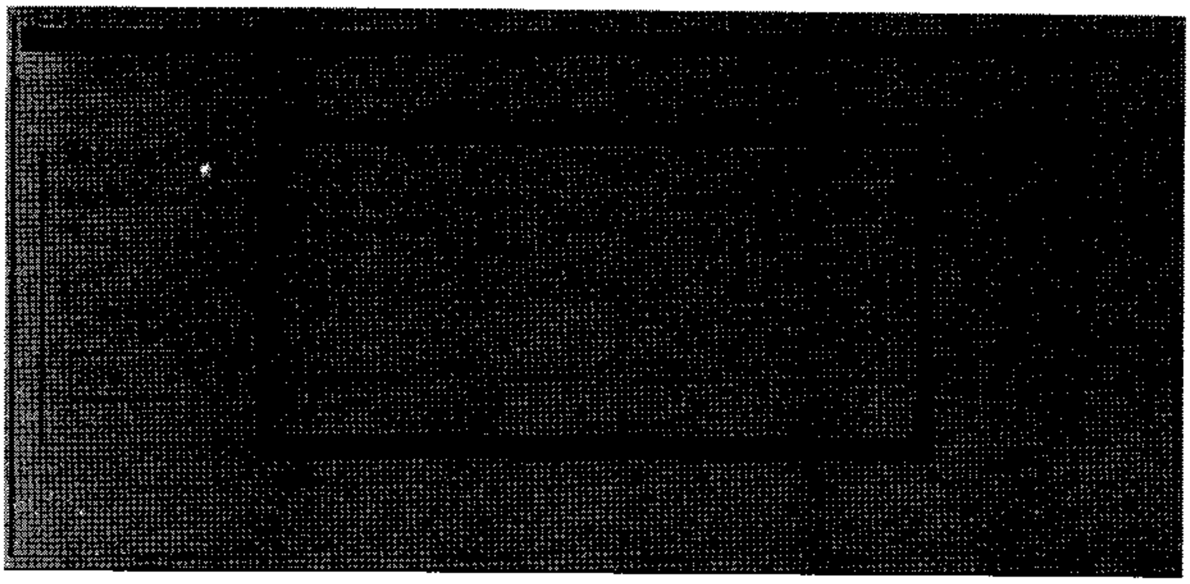

FIGURE 4.3 SIZE OPTION FOR WTONECG AND WTENV

Figure 4.4 shows the input window. The data that is required are the coordinates, weight, moment of inertia for each of the components of the airplane, and useful loads for the loading. The inertia of small components may be neglected with no appreciable effect on the total inertia of the airplane.

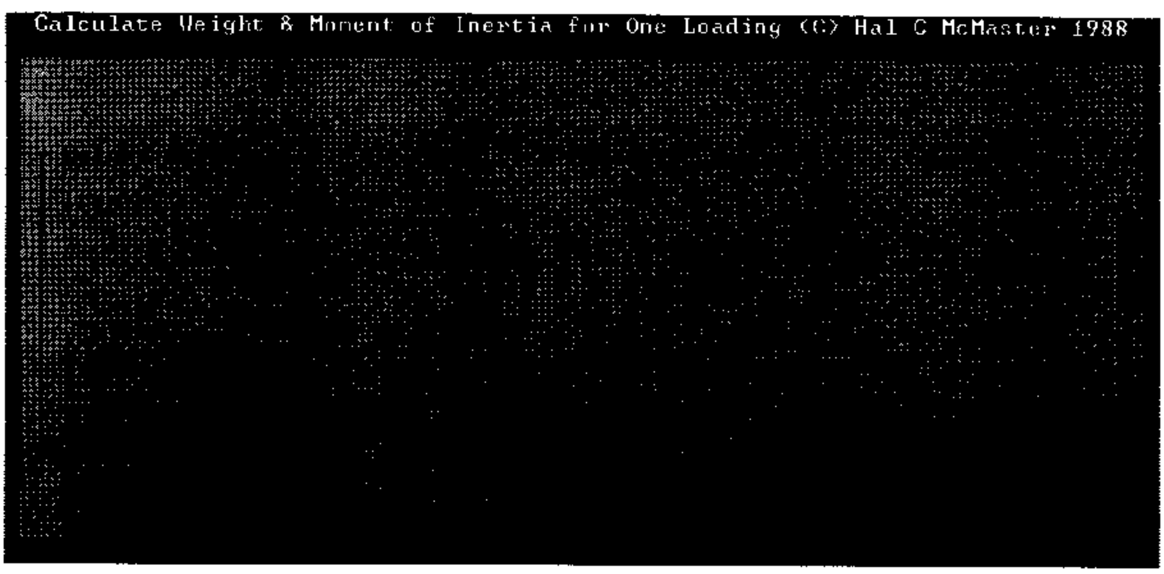

FIGURE 4.4 WTONECG INPUT WINDOW

5. ENVELOPE OF LOADING CONDITIONS.

5.1 WTENV DESCRIPTION.

The module WTENV calculates the envelope of discretionary useful loading. It uses the same database as WTONECG (section 4). The database contains the component weight data and location dimensions. This weight data comes from WTESTIMA or actual known weights; the location dimensions come from the three-view drawing.

WTENV can be used to create or modify the database by adding, deleting, changing, and moving component data. The minimum flight weight is calculated, and the envelope of enclosing all possible loadings is calculated. From the plot of the envelope of useful loadings, the four structural limit points can be selected to include the most desirable and practical loadings. See section 4 for additional discussion of the weight database.

5.2 RUNNING WTENV.

To run WTENV, select it from the main menu window. The first window for WTENV (as in WTONECG) is used to open a database; it includes four menu options: File, Notepad, Size, and Color.

WTENV uses the same database file as WTONECG. When the WTENV module is first opened, the File menu includes only two options: *Open Weight Database* or *Return to Main Menu.* You must select *Open Weight Database* to open an existing file or to create a new database. When you open a file, you will see a message shown in figure 4.2. Click *OK* to continue. The file that you select is not checked to be sure it is a database file. If the data in the input window appears strange, then you did not open a database file. Two examples of database files, WTENV36 and M2002576, are included on the installation disk.

5.2.1 Input Window.

After a file is opened, the input window appears as shown in figure 5.1. The window also includes five menu options: File, Notepad, Edit, Size, and Color.

After a database file is opened, the File menu is used to store and print data. *Open Weight Database* allows you to retrieve a previously created and saved database file. *Save Weight Database As* will allow the database to be saved to a file. *Save Weight Envelope As* allows the calculations to be saved to a file. *Print Weight Database and Envelope* allows you to perform the calculations and print both the database and the results of the calculations to a printer or file. *Print Weight Envelope only* allows you to perform the calculations and send only the results to a file or printer. *Return to Main Menu* exits from WTENV and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program, where you can review your input and output files.

If you want to plot the flight envelope, you should save the database and envelope to a file. To use the FAR23 Plot program, the filename must have the extension *.WTS.*

5.3 WTENV OUTPUT.

The output from WTENV is the envelope of useful loads and includes the weight and c.g. of the airplane for given loading conditions. This data is used in FLTLOADS (section 11).

5.4 GRAPHICS.

The separate graphics program FAR23 Plot can be used to draw the weight envelope of discretionary useful loading and the envelope of structural weight limits. An example of this plot is shown in figure 5.2. The FAR23 Plot program is described in the appendix of reference 1.

To use the FAR23 Plot program, the filename must have the extension *.WTS.*

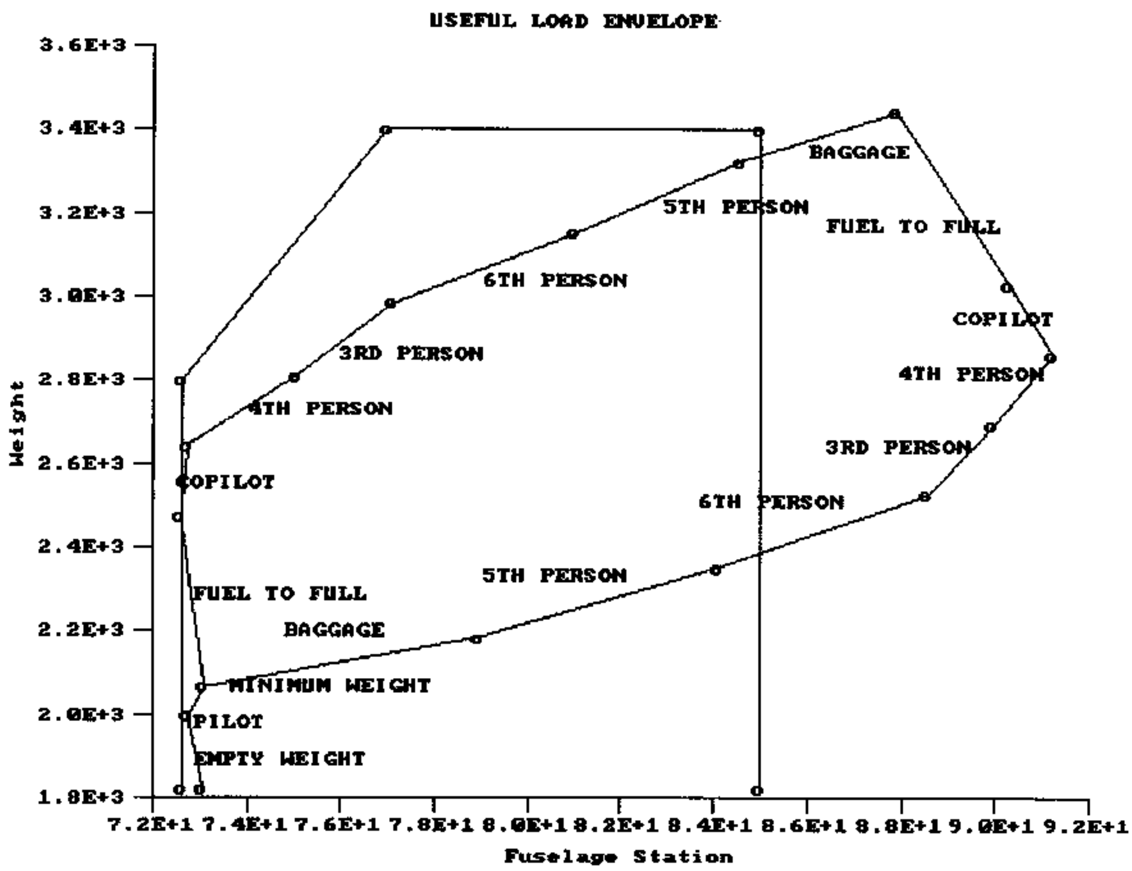

FIGURE 5.2 EXAMPLE OF USEFUL LOAD ENVELOPE AND STRUCTURAL LIMITS

6. AERODYNAMIC SURFACE GEOMETRY.

6.1 WINGGEOM DESCRIPTION.

The geometric properties for all aerodynamic surfaces on the airplane are calculated by the program WINGGEOM. The aerodynamic surfaces include the wing, aileron, aileron tab, flap, horizontal tail, elevator, elevator tab, vertical tail, rudder, and rudder tab.

WINGGEOM must be used to analyze each aerodynamic surface. For each surface, the user enters the coordinates to define the leading and trailing edges of the surface. The program divides the surface into elements, and calculates the area of each element.

The input required for this program includes the coordinates of the leading and trailing edge of the aerodynamic surface. Two points define a straight leading or trailing edge. Three points can be used to define the leading edge of a wing with a leading edge extension at the inboard end of the wing. Three points would also be used to define a straight leading edge with a raked tip. A complex or curved leading or trailing edge can be defined by a series of points assuming short straight lines between points.

6.2 RUNNING WINGGEOM.

To run WINGGEOM, select the WINGGEOM button from the main menu window. You will see the main window for this program as shown in figure 6.1.

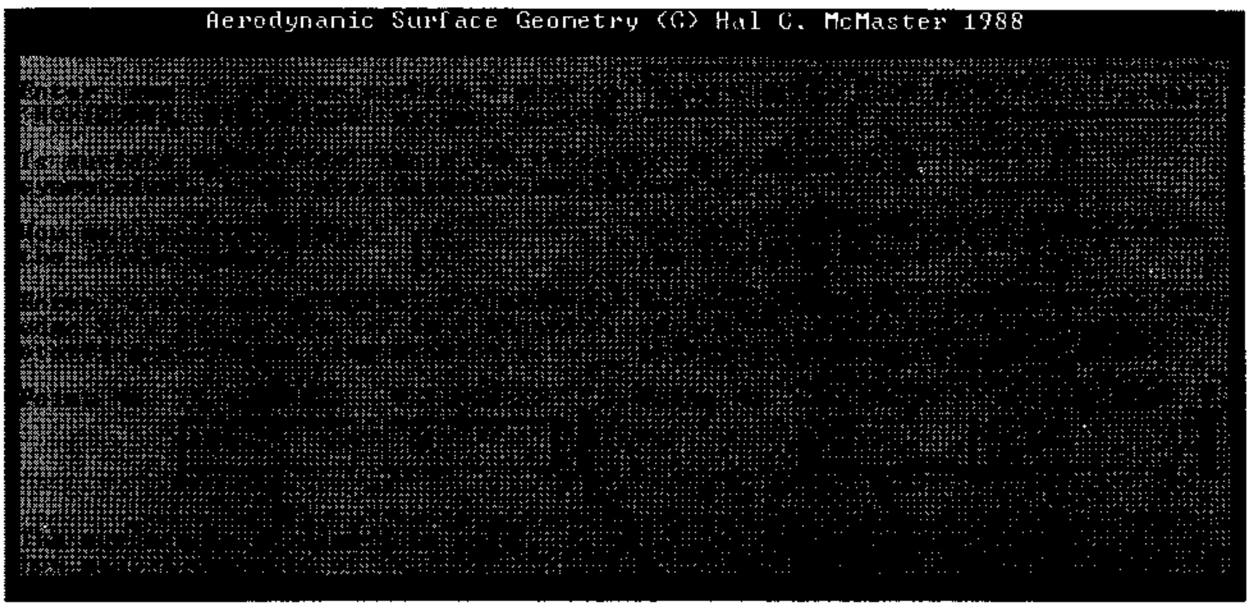

FIGURE 6.1 WINGGEOM INPUT WINDOW

6.3 WINGGEOM OUTPUT.

The module WINGGEOM calculates the area, aspect ratio, mean aerodynamic chord (MAC), and the butt line and fuselage station of the leading edge of the MAC. This output data is needed as input to the modules STRSPEED for structural speeds (section 7), AIRLOADS and AIRLOAD4 for air loads (sections 9 and 10), FLTLOADS for the flight envelope (section 11), SELECT for the selection of critical loads (section 12), and ONENGOUT for the one-engine-out loads (section 22).

The output echoes the input parameters, including the coordinates of the leading and trailing edges, then prints the results. Optional output includes the data for the sections that the surface was divided into. Appendices A and B of reference 1 show the output of WINGGEOM for two example airplanes. WINGGEOM was used to generate output for the following components: wing, aileron (forward and aft of the hinge line), flap, vertical tail, rudder, horizontal tail, elevator (forward and aft of the hinge line), and elevator tab.

6.4 GRAPHICS.

The aerodynamic surfaces can be drawn with the GEOMPLOT graphing program. This program is described in the appendix of reference 1, and examples of the figures are shown in appendices A and B of reference 1.

The output files from WINGGEOM are read by the plotting program. The filenames must have the extension *.PLT*.

The results from several surfaces can be plotted together. For example, the wing, aileron, and flap can be plotted together. To do this, plot the wing first and overlay the aileron and flaps. An example of this plot is shown in figure 6.2.

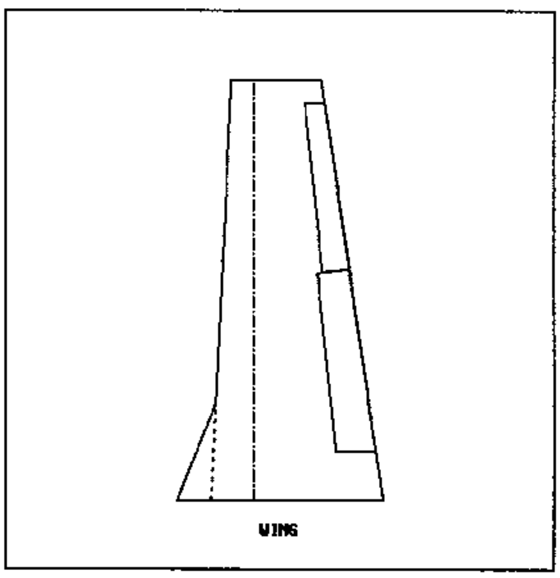

FIGURE 6.2 EXAMPLE OF AERODYNAMIC SURFACES PLOT

Then the air speed and Mach number can be calculated:

$$\sigma = (1-0.000006879h)^{4.258}$$

$$V_{C-TAS} = \frac{V_{C-EAS}}{\sigma^{0.5}}$$

$$V_{D-TAS} = \frac{V_{D-EAS}}{\sigma^{0.5}}$$

$$M_C = \frac{V_{C-TAS}}{a}$$

$$M_D = \frac{V_{D-TAS}}{a}$$

where:

σ = ratio of density at altitude to density at sea level
V_C = design cruise air speed (knots)
V_D = design dive air speed (knots)
M_C = Mach number at the design cruise speed V_C
M_D = Mach number at the design dive speed V_D
EAS = equivalent air speed
TAS = true air speed

7.2 FAR 23 REGULATIONS.

The requirements for the design air speeds are defined in FAR 23.335, and the limit maneuvering load factors must meet the requirements of FAR 23.337.

7.2.1 FAR 23.335 Design Air Speeds.

Except as provided in paragraph a.(4) of this section, the selected design air speeds are equivalent air speeds (EAS).

a. For design cruising speed, V_C, the following apply:

(1) V_C (in knots) may not be less than

(a) $33\sqrt{W/S}$ (for normal, utility, and commuter category airplanes) and

(b) $36\sqrt{W/S}$ (for acrobatic category airplanes).

(2) For values of *W/S* more than 20, the multiplying factors may be decreased linearly with *W/S* to a value of 28.6 where *W/S* = 100.

(3) V_C need not be more than 0.9 V_H at sea level.

7. STRUCTURAL DESIGN SPEEDS AND MANEUVERING LOAD FACTORS.

7.1 STRSPEED DESCRIPTION.

The structural design speeds and maneuvering load factors are calculated by the module STRSPEED. This module lets you choose the category in which you will certify the airplane: normal, utility, or acrobatic. STRSPEED calculates the minimum structural design speeds and load factors and then verifies that the chosen structural design speeds are greater than the minimum requirements and that the margins between speeds are greater than the requirements. If necessary, the speeds are adjusted to meet the requirements relative to cruise speed.

The structural design speeds and maneuver load factors must be selected so that they are greater than the minimum values specified in FAR 23.335 (design air speeds) and FAR 23.337 (limit maneuvering load factors). Also, the relationships between the structural design speeds must meet the minimum margins between speeds that are specified in FAR 23.335.

The module STRSPEED calculates the minimum structural design speeds and load factors and then verifies that the chosen structural design speeds are greater than the minimum requirements and that the margins between speeds are greater than the requirements. If necessary, the speeds are adjusted to meet the requirements relative to cruise speed.

The maneuvering loads factors are defined in FAR 23.337 and summarized in table 7.1.

TABLE 7.1 MANEUVERING LOAD FACTOR LIMITS

CATEGORY	POSITIVE LOAD FACTOR	NEGATIVE LOAD FACTOR
Normal	2.1 + [24000/(W+10000)] but not greater than 3.8	-0.4 x positive load factor
Utility	4.4	-0.4 x positive load factor
Acrobatic	6.0	-0.5 x positive load factor

After the design speeds are determined, the Mach limitations at shoulder altitude are calculated for V_C and V_D. To calculate the limiting values of M_C and M_D, the temperature and speed of sound at altitude are calculated from

$$T = 59.0 - 0.003566h$$
$$a = 29.02(T+459.4)^{0.5}$$

where:

T = temperature at altitude (°F)
h = altitude (feet)
a = speed of sound (knots)

(1) V_B may not be less than the speed determined by the intersection of the line representing the maximum positive lift $C_{n\ max}$ and the line representing the rough air gust velocity in the gust V-n diagram, or $\sqrt{n_g}\,V_{s1}$, whichever is less, where:

(a) n_g is the positive airplane gust load factor due to gust at speed V_C (in accordance with FAR 23.341) and at the particular weight under consideration, and

(b) V_{S1} is the stalling speed with the flaps retracted at the particular weight under consideration.

(2) V_B need not be greater than V_C.

7.2.2 FAR 23.337 Limit Maneuvering Load Factors.

a. The positive limit maneuvering load factor n may not be less than

(1) 2.1+[24,000/(W+10,000)] for normal and commuter category airplanes, except that n need not be more than 3.8,

(2) 4.4 for utility category airplanes, or

(3) 6.0 for acrobatic category airplanes.

b. The negative limit maneuvering load factor may not be less than

(1) 0.4 times the positive load factor for the normal utility and commuter categories or
(2) 0.5 times the positive load factor for the acrobatic category.

c. Maneuvering load factors lower than those specified in this section may be used if the airplane has design features that make it impossible to exceed these values in flight.

7.3 RUNNING STRSPEED.

To run STRSPEED, select the STRSPEED button from the main menu window. You will see the main window for the module as shown in figure 7.1.

7.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform

(4) At altitudes where an M_D is established, a cruising speed M_C limited by compressibility may be selected.

b. For design dive speed, V_D, the following apply:

(1) V_D/M_D may not be less than 1.25 V_C/M_C.

(2) With V_{Cmin} (the required minimum design cruising speed) V_D (in knots) may not be less than

(a) 1.40 V_{Cmin} (for normal and commuter category airplanes);
(b) 1.50 V_{Cmin} (for utility category airplanes); and
(c) 1.55 V_{Cmin} (for acrobatic category airplanes).

(3) For values of W/S more than 20, the multiplying factors in paragraph b.(2) of this section may be decreased linearly with W/S to a value of 1.35 where $W/S = 100$.

(4) Compliance with paragraphs b.(1) and (2) of this section need not be shown if V_D/M_D is selected so that the minimum speed margin between V_C/M_C and V_D/M_D is the greater of the following:

(a) the speed increase resulting when, from the initial condition of stabilized flight of $V_C/M_{C,K}$ the airplane is assumed to be upset, flown for 20 seconds along a flight path 7.5° below the initial path, and then pulled up with a load factor of 1.5 (0.5 g acceleration increment). At least 75 percent maximum continuous power for reciprocating engines, and maximum cruising power for turbines, or, if less, the power required for V_C/M_C for both kinds of engines must be assumed until the pullup is initiated, at which point power reduction and pilot-controlled drag devices may be used, and

(b) mach 0.05 (at altitudes where an M_D is established).

c. For design maneuvering speed, V_A, the following applies:

(1) V_A may not be less than $V_s\sqrt{n}$ where

(a) V_S is a computed stalling speed with flaps retracted at the design weight, normally based on the maximum airplane normal force coefficients, C_{NA}; and

(b) n is the limit maneuvering load factor used in design.

(2) The value of V_A need not exceed the value of V_C used in design.

d. For design speed for maximum gust intensity, V_B, the following apply:

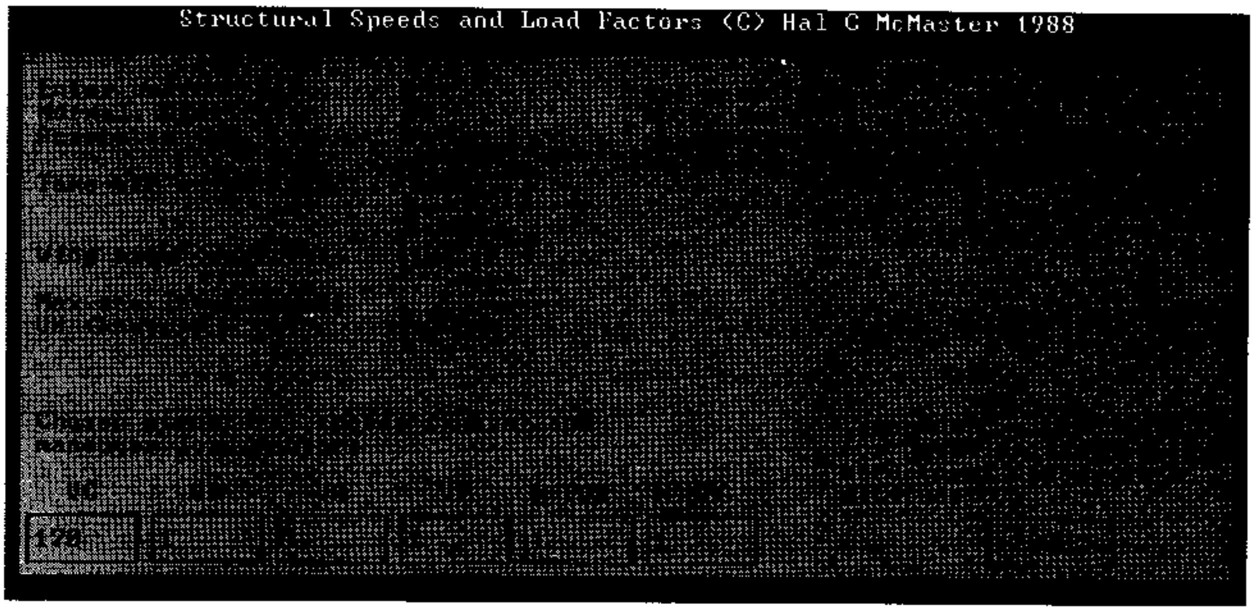

FIGURE 7.2 STRSPEED ALTERNATE INPUT WINDOW

7.3.2 Running the Analysis.

After all input are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results. The first option saves the output to a file, and the second option prints the output.

7.4 STRSPEED OUTPUT.

STRSPEED calculates the design speeds, load factors, and Mach numbers (M_C, M_D). The minimum values are calculated for V_C, V_D, V_A, and V_F, and for the positive and negative load factors. If you chose a design speed, then the other speeds are adjusted to meet the requirements. The calculated values are used in MACHLIM, FLTLOADS, AILERON, and FLAPLOAD (sections 8, 11, 13, and 14 respectively).

the calculations and print the output file to a serial or parallel printer. ***Return to Main Menu*** exits from STRSPEED and returns to the FAR23 Loads Main Menu.

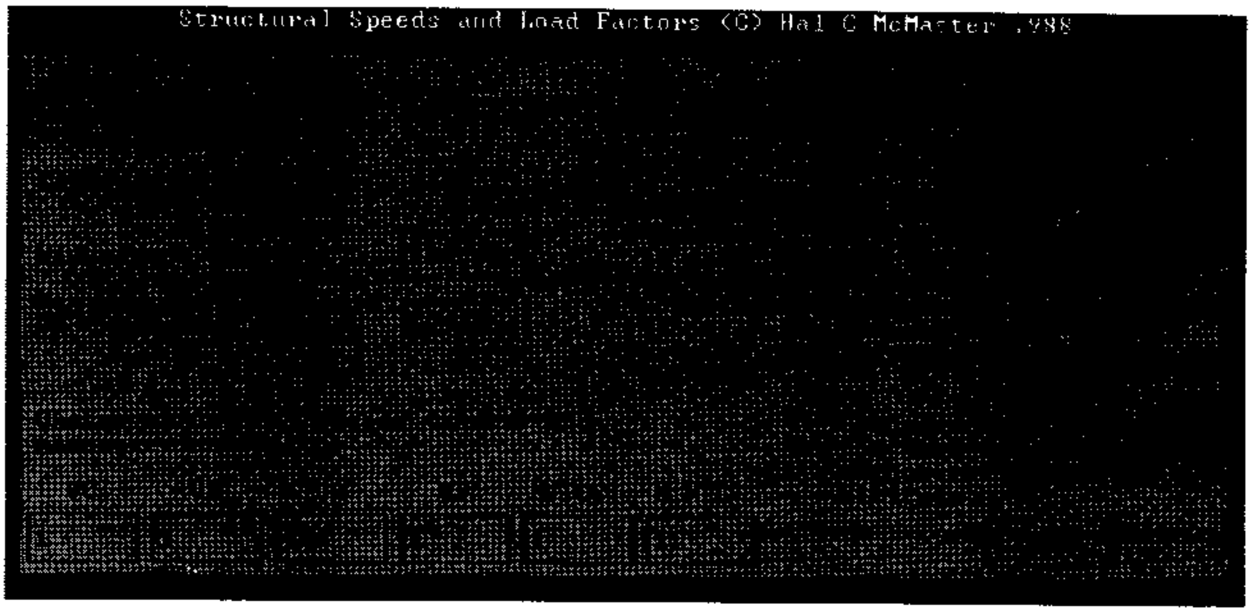

FIGURE 7.1 STRSPEED INPUT WINDOW

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input required for STRSPEED includes the category of airplane (normal, utility, or acrobatic), the takeoff weight, wing area, maximum speed at sea level (V_H), and the shoulder altitude.

The stalling speed with flaps extended and with flaps retracted can be entered if known, or they can be calculated by STRSPEED. If you know the stalling speed, answer Y to the question, then enter the speeds. If you want to calculate the stalling speeds, answer N. You will then be asked to enter the maximum lift coefficients, $C_{L\text{-}w}$ and $C_{L\text{-}f}$, as shown in figure 7.2.

The design speeds (V_C, V_D, V_A, V_F) and load factors ($+n$, $-n$) can be entered, or you can allow the program to calculate these. Enter 1 for any value you want calculated. You can enter some of the design speeds and let the program calculate the remaining values.

Note: In this window, it is recommended that you use *Tab* to move from field to field. If you open a previously created file, you must tab through all the fields after they are filled to complete the data entry. Otherwise the program may give a "Divide by zero" error. Also, if you use the mouse to move between fields, you may get the same error message.

The Color option allows you to change the color scheme displayed on your window.

The input for MACHLIM includes the Mach number at design cruising speed (M_C), the Mach number at design dive speed (M_D), the shoulder altitude, and the maximum operating altitude. An altitude increment is also required; this is used to determine the altitudes of interest between the shoulder and operating altitudes. The altitudes are entered in feet.

The Mach numbers at design cruise and dive speeds are calculated in STRSPEED (section 7).

8.2.2 Running the Analysis.

After all input are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second selection also includes the option to send the output directly to a printer.

8.3 MACHLIM OUTPUT.

The output from MACHLIM includes the air speeds at altitudes between the shoulder altitude and the operating altitude. This data can be plotted on the flight limits diagram using FAR23 Plot.

All speeds are given in knots equivalent air speed (KEAS), and the altitude is in feet.

8.4 GRAPHICS.

The separate graphics program FAR23 Plot can be used to draw the Mach limits lines on the flight limit diagram. The FAR23 Plot program is described in the appendix of reference 1.

To plot the data, the output file from MACHLIM must have a filename with the extension *.SPD*. An example of a flight limit diagram is shown in figure 8.2.

8. MACH LIMITATIONS.

8.1 MACHLIM DESCRIPTION.

The MACHLIM module determines the Mach limitations for the flight envelope diagram. For a constant Mach number, the equivalent air speed is calculated at altitudes from the shoulder altitude to the maximum operating altitude. The equations for calculating equivalent air speed are given in section 7.

8.2 RUNNING MACHLIM.

To run MACHLIM, select the MACHLIM button from the main menu window. The main input window for MACHLIM is shown in figure 8.1.

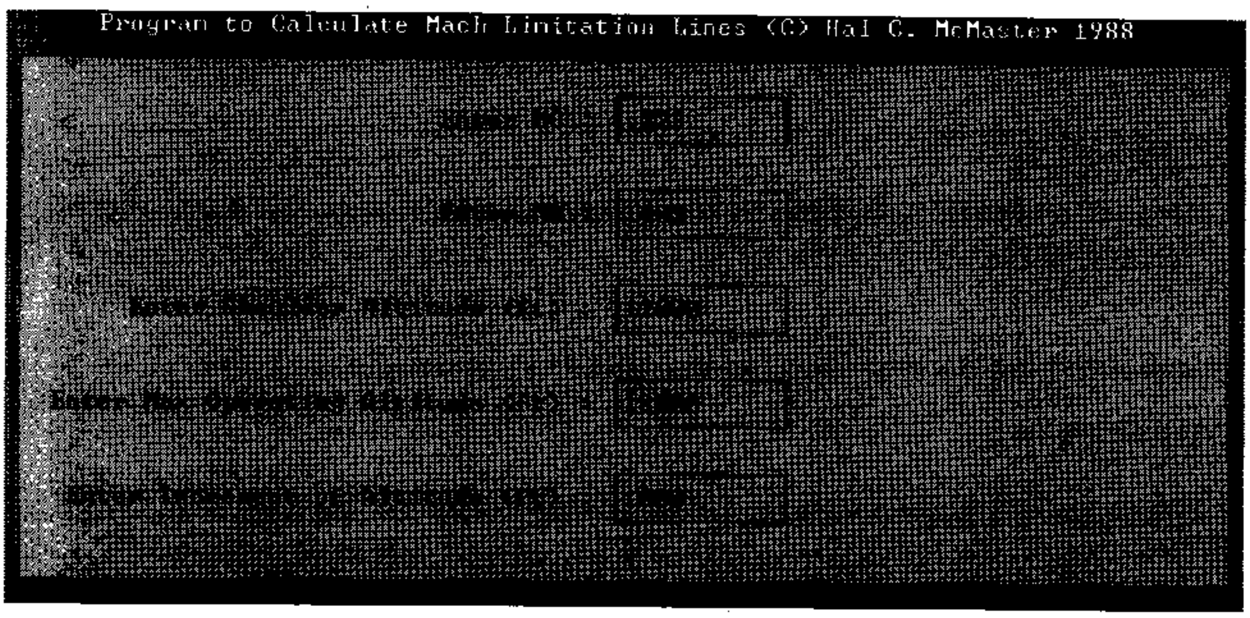

FIGURE 8.1 MACHLIM INPUT WINDOW

8.2.1 Input Window.

The input window is displayed when the module starts, and is used to specify the parameters for the analysis. This window also includes three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and send the output data to a file or printer. *Return to Main Menu* exits from MACHLIM and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program, where you can review your input and output files.

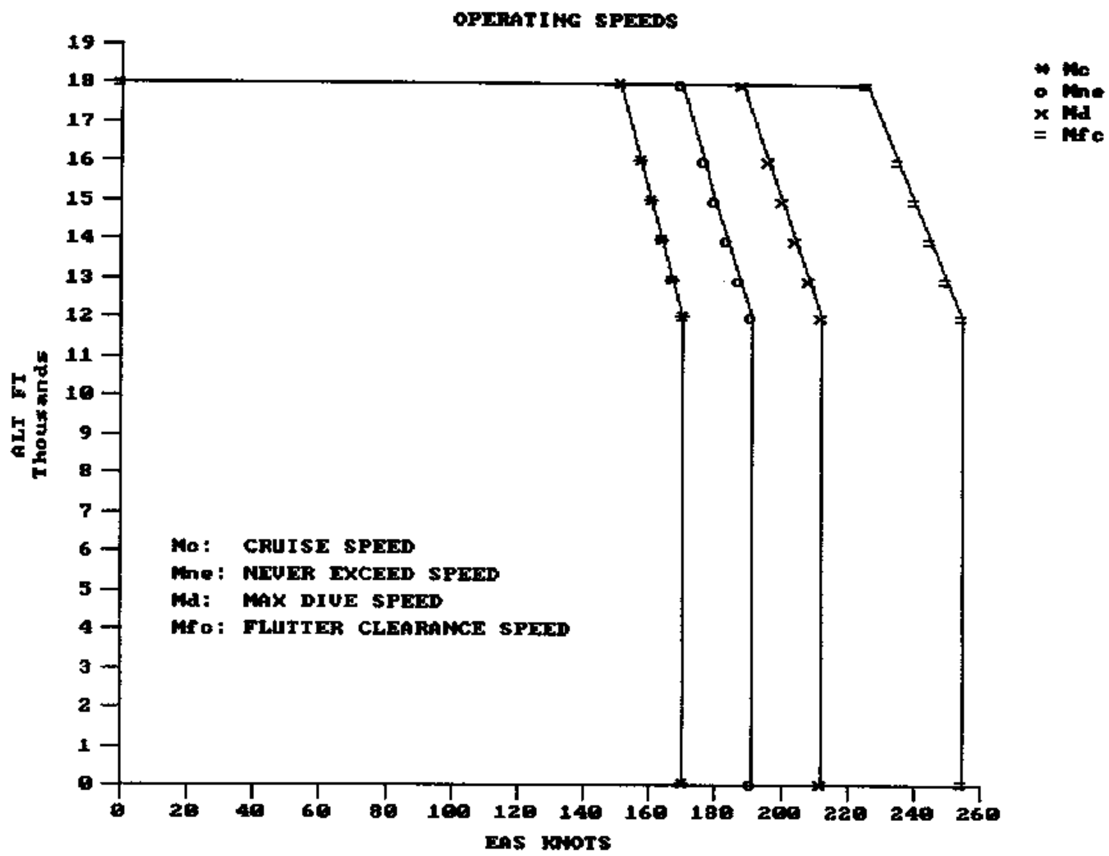

FIGURE 8.2 EXAMPLE OF FLIGHT LIMIT DIAGRAM

where:

cc_l	=	local chordwise lift distribution
$\bar{c}C_L$	=	chordwise lift distribution for the wing
Λ	=	angle of sweepback
y	=	wing station
b	=	wing span

9.1.2 Air Loads.

After determining the critical conditions for the wing (see section 12), the actual air loads can be calculated. The lift coefficient, C_L, and speed for each critical wing condition is calculated by FLTLOADS (see section 11). Using this data, AIRLOADS calculates the spanwise air load distributions for lift, drag, and pitching moment for each of the critical wing conditions. Then the shear, bending moments, and torsion air loads are calculated along the quarter chord.

9.2 FAR 23 REGULATIONS.

The regulations for air loads are defined in FARs 23.301, 23.349, and 23.455 and repeated here for convenience.

9.2.1 FAR 23.301 Loads.

a. Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

b. Unless otherwise provided, the air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the airplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution on canard and tandem wing configurations must be validated by flight test measurement unless the methods used for determining those loading conditions are shown to be reliable or conservative on the configuration under consideration.

c. If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

d. Simplified structural design criteria may be used if they result in design loads not less than those prescribed in FARs 23.331 through 23.521. For conventional, single-engine airplanes with design weights of 6,000 pounds or less, the design criteria of Appendix A of Part 23 are an approved equivalent of FARs 23.321 through 23.459. If Appendix A is used, the entire appendix must be substituted for the corresponding sections of Part 23.

9. AERODYNAMIC COEFFICIENTS AND AIRLOADS.

9.1 AIRLOADS DESCRIPTION.

The AIRLOADS module is used to calculate the aerodynamic coefficients and wing air loads. AIRLOADS is used twice. First, it is used to calculate the aerodynamic coefficients. Then, after determining the critical wing load conditions (section 12), it is used to calculate the actual air loads for the critical wing load conditions.

The AIRLOADS and AIRLOAD4 (section 10) modules are similar in function. However, AIRLOAD4 should be used to calculate the aerodynamic coefficients and wing air loads if the sweepback of the 25% chord is greater than 15°. If the Mach number is greater than 0.5, then AIRLOAD4 should be used to calculate the air loads. Either AIRLOADS or AIRLOAD4 can be used to calculate the aerodynamic coefficients if the sweepback is less than 15°.

9.1.1 Aerodynamic Coefficients.

AIRLOADS calculates the basic and additive spanwise aerodynamic lift coefficient distributions for the wing. It combines these with the spanwise lift coefficient distribution for any specific total wing lift coefficient and then calculates the associated spanwise drag and moment coefficients for that wing C_L.

AIRLOADS calculates the stall lift coefficient and angle of attack for the wing. The pitching moment coefficient of the fuselage and nacelle is calculated and added to the total wing moment coefficient to provide lift, drag, and moment coefficients for the airplane-less-tail condition for any C_L. The drag and moment of the extended landing gear are calculated and added to the airplane-less-tail. The sea level equations for lift, drag, and moment are formulated. These equations are used to make the balancing calculations for the V-n diagrams (see section 11).

The spanwise lift distribution on the wing is determined by Schrenk's method [1]. For additive lift, the Schrenk method averages the chordwise distribution with an elliptical chord distribution of the same wing area as if there was a constant airfoil and no aerodynamic twist. For the basic lift, the Schrenk method averages the zero lift distribution and the elliptical distribution for zero lift. The zero lift distribution is the local chord times slope of the lift times the angle of attack relative to the zero lift line of the wing.

Tau (τ) is a correction factor for the slope of the lift curve that accounts for the deviation of the wing plan form from an ellipse [1]. This factor is required input for AIRLOADS and can be calculated during data input.

If the sweepback of the quarter chord is greater than 15°, then the lift distribution is calculated from [3]:

$$\left(\frac{cc_l}{\bar{c}C_L}\right)_{\Lambda} = \left(\frac{cc_l}{\bar{c}C_L}\right)_{\Lambda=0} - \left(1-\frac{2y}{b}\right)[2(1-\cos\Lambda)]$$

(b) Sufficient deflection at V_C, where V_C is more than V_A, to produce a rate of roll not less than obtained in paragraph a.(2)(a) of this section.

(c) Sufficient deflection at V_D to produce a rate of roll not less than one-third of that obtained in paragraph a.(2)(a) of this section.

b. [Reserved]

9.3 RUNNING AIRLOADS.

To run the module AIRLOADS, select the button from the main menu window. The first input window will be displayed as shown in figure 9.1.

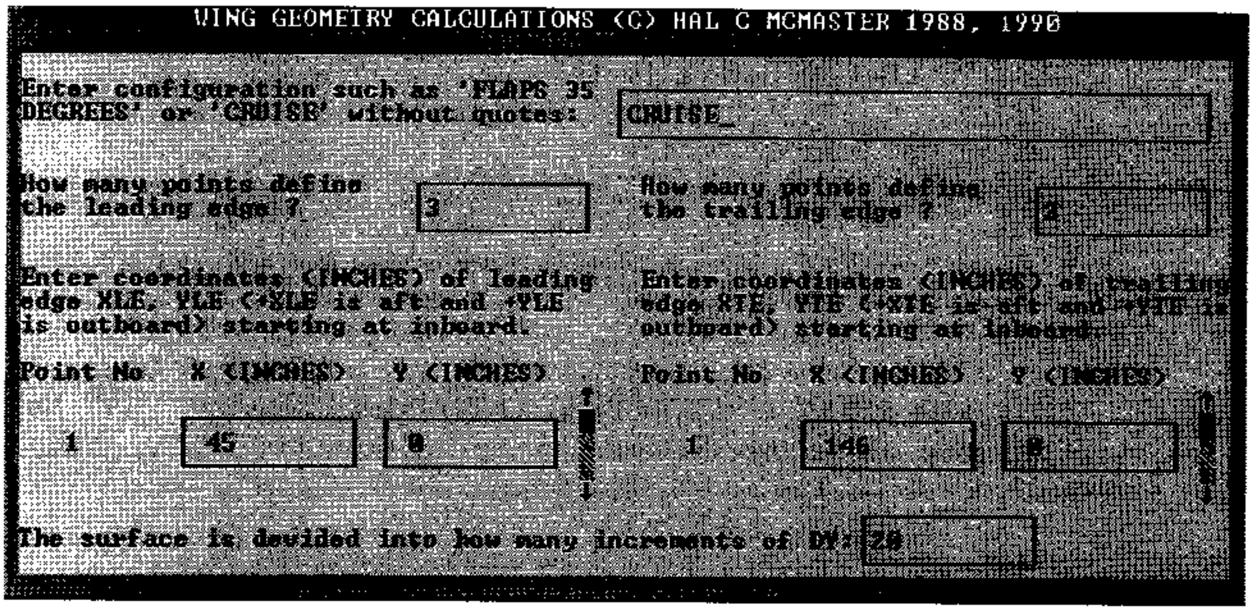

FIGURE 9.1 AIRLOADS FIRST INPUT WINDOW

9.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes twelve menu options: File, Notepad, Color, and Pg1-Pg9.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and send the output data to a printer or file. *Return to Main Menu* exits from the AIRLOADS program and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files, and the Color option allows you to change the color scheme displayed on your window.

9.2.2 FAR 23.349 Rolling Conditions.

The wing and wing bracing must be designed for the following conditions:

a. Unsymmetrical wing loads appropriate to the category. Unless the following values result in unrealistic loads, the rolling accelerations may be obtained by modifying the symmetrical flight conditions in FAR 23.333(d) as follows:

   (1) For acrobatic category, in conditions A and F, assume that 100 percent of the semispan wing air load acts on one side of the plane of symmetry and 60 percent of this load acts on the other side.

   (2) For normal, utility, and commuter categories, in Condition A, assume that 100 percent of the semispan wing air load acts on one side of the airplane, and 70 percent of this load acts on the other side. For airplanes of more than 1,000 pounds design weight, the latter percentage may be increased linearly with weight up through 75 percent at 12,500 pounds to the maximum gross weight of the airplane.

b. The wing and wing bracing must be designed for the loads resulting from the aileron deflections and speeds specified in FAR 23.455, in combination with an airplane load factor of at least two thirds of the positive maneuvering load factor used for design. Unless the following values result in unrealistic loads, the effect of aileron displacement on wing torsion may be accounted for by adding the following increment to the basic airfoil moment coefficient over the aileron portion of the span in the critical condition determined in FAR 23.333(d):

$$\Delta C_m = -0.01\delta$$

where:

ΔC_m is the moment coefficient increment, and
δ is the down aileron deflection in degrees in the critical condition.

9.2.3 FAR 23.455 Ailerons.

a. The ailerons must be designed for the loads to which they are subjected

   (1) in the neutral position during symmetrical flight conditions and

   (2) by the following deflections (except as limited by pilot effort) during unsymmetrical flight conditions:

      (a) Sudden maximum displacement of the aileron control at V_A. Suitable allowance may be made for control system deflections.

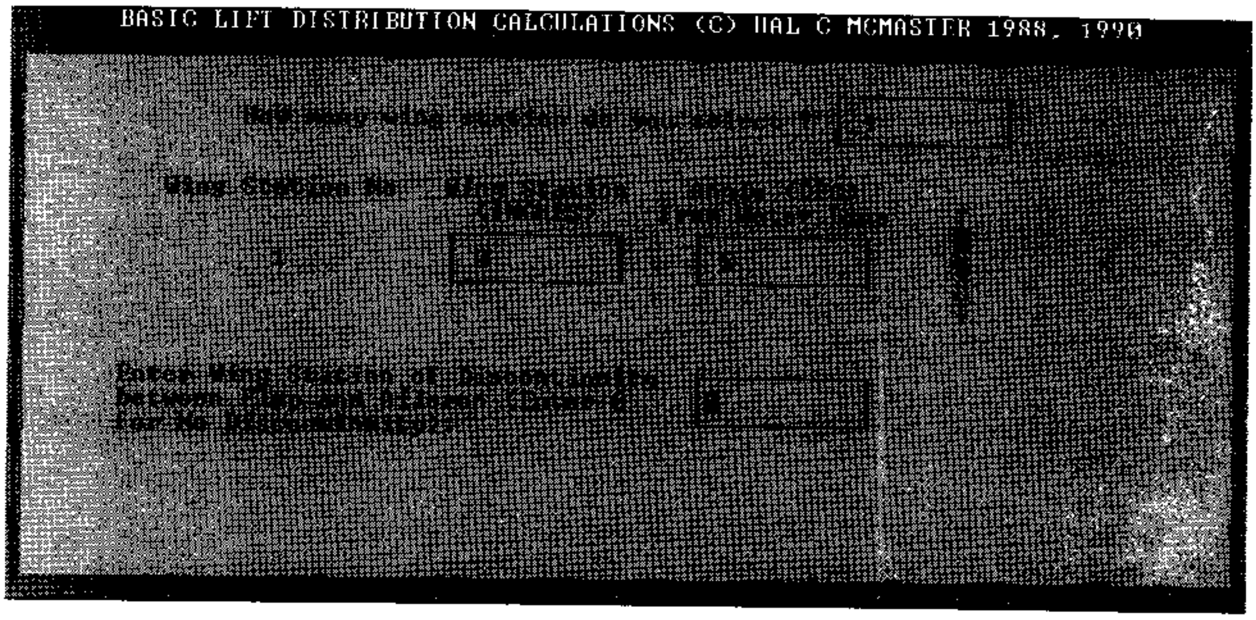

FIGURE 9.3 AIRLOADS THIRD INPUT WINDOW

On the fourth window, shown in figure 9.4a, the first question asks if you want to calculate the stall C_L. If you are calculating the aerodynamic coefficients, then you want to answer Y. If you are calculating the air loads, then answer N. If you answer N, then no additional input is required on this window as shown in figure 9.4b.

If you want to calculate the stall C_L, then enter the additional data. RN is Reynolds number.

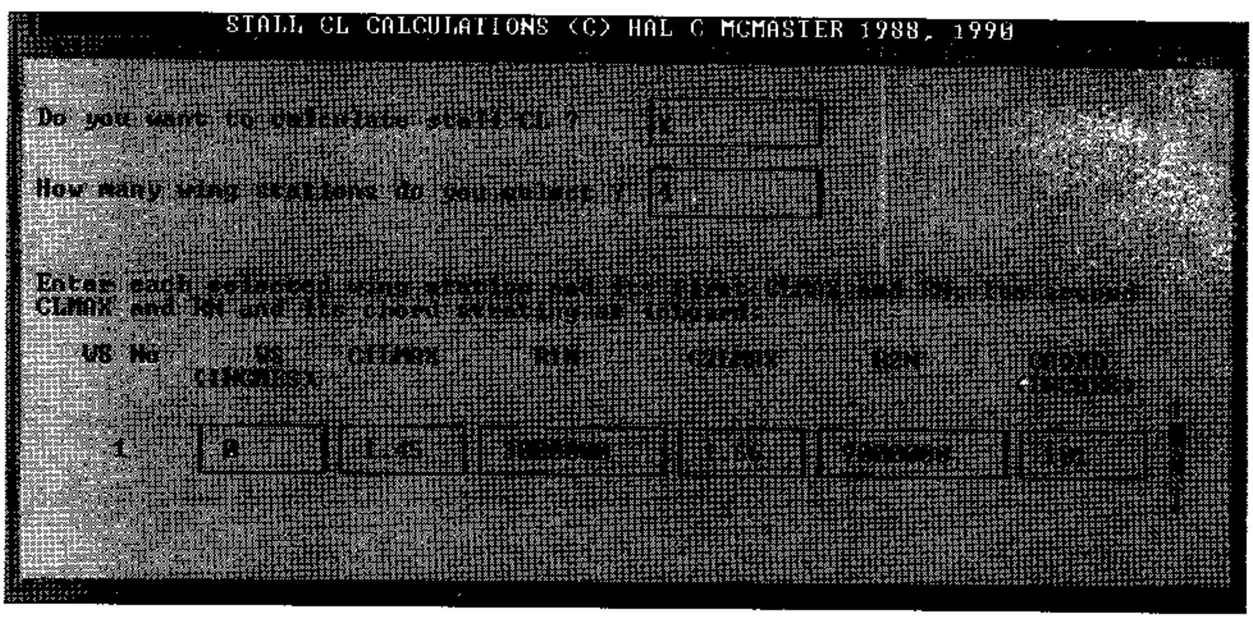

FIGURE 9.4a AIRLOADS FOURTH INPUT WINDOW

The options Pg1-Pg9 are for the nine input windows used to enter the data required for the air loads analysis. If you are calculating the aerodynamic coefficients, you do not need to enter data on the seventh window. If you are calculating the air loads, you do not need to enter data on the fourth window. The eighth window is used only for landing gear aerodynamic coefficients, and the ninth window is only for calculating tau (τ).

Note: If you open an existing data file in AIRLOADS, you may get an error message about reading past the end of file. This means that the data file does not have enough data for all the input windows and is probably missing data for the seventh and eighth windows. You should check all the windows to verify the data before running the analysis.

On the first window, the geometry data is entered, including the coordinates for the leading and trailing edges.

The parameters required for the additive lift distribution calculations are entered on the second window shown in figure 9.2, and the data for basic lift distribution are entered on the third window as shown in figure 9.3.

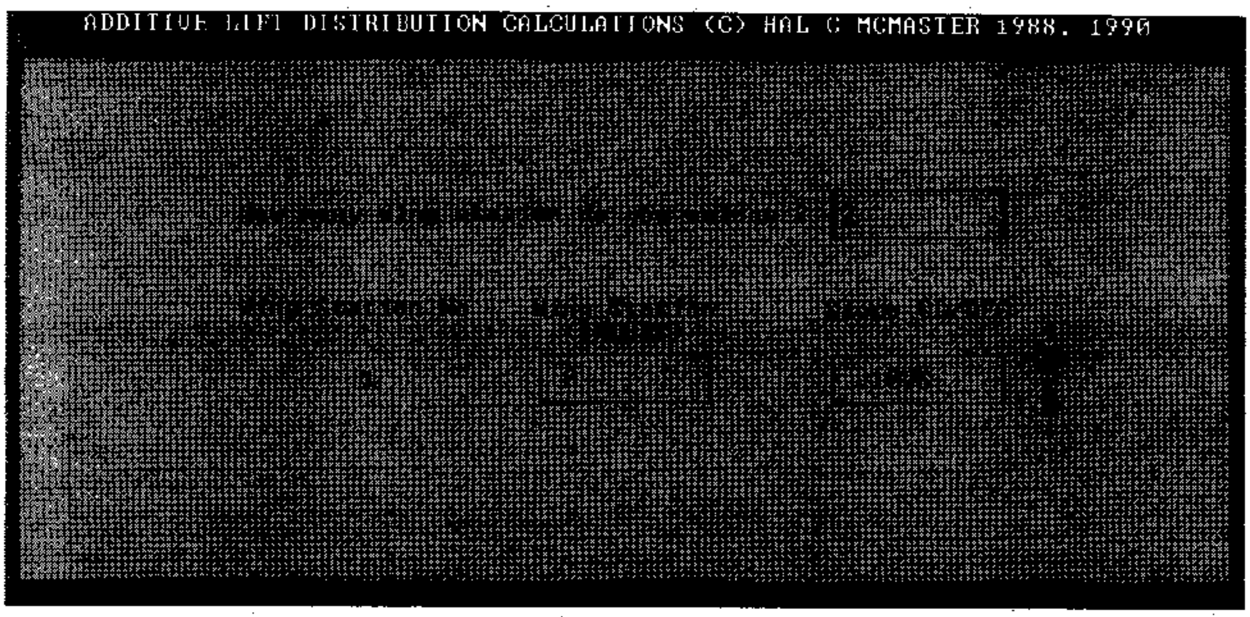

FIGURE 9.2 AIRLOADS SECOND INPUT WINDOW

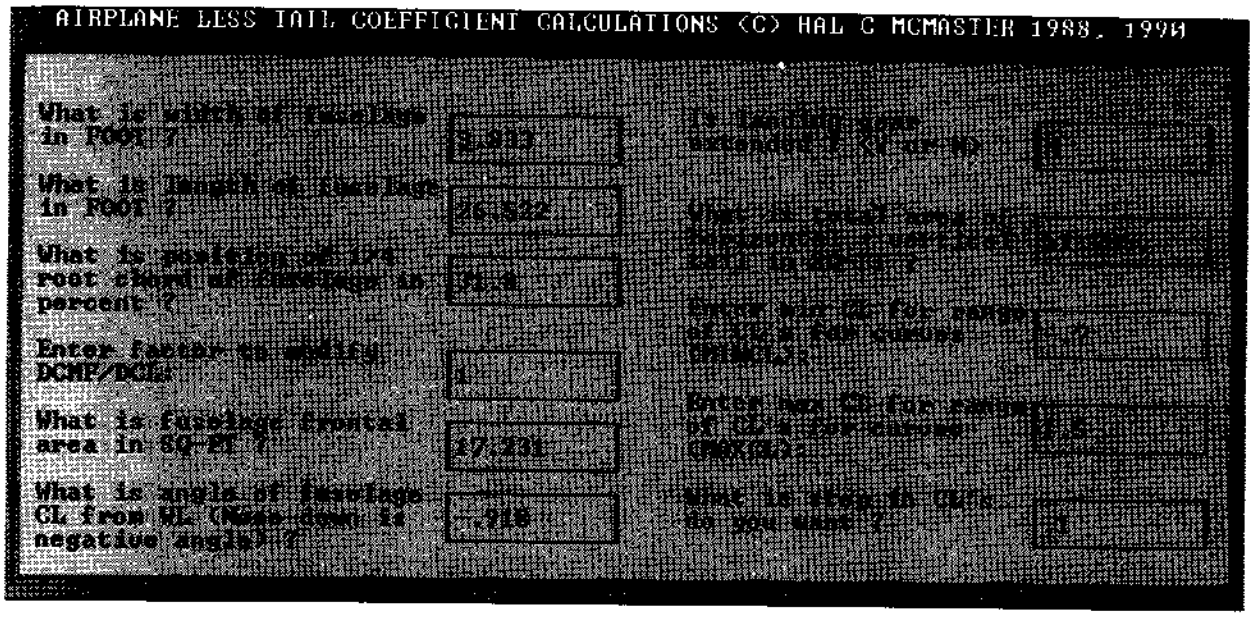

FIGURE 9.6 AIRLOADS SIXTH INPUT WINDOW

On the seventh window, shown in figure 9.7a, the first question asks if you want to calculate the air loads. If you are calculating the air loads, then you want to answer Y. If you are not calculating the air loads, then answer N. If you answer N, then no additional input is required on this window.

If you answer Y, then enter the additional data as shown in figure 9.7b.

If you opened an existing input data file, you will need to check the values on the seventh and eighth windows to be sure they are correct.

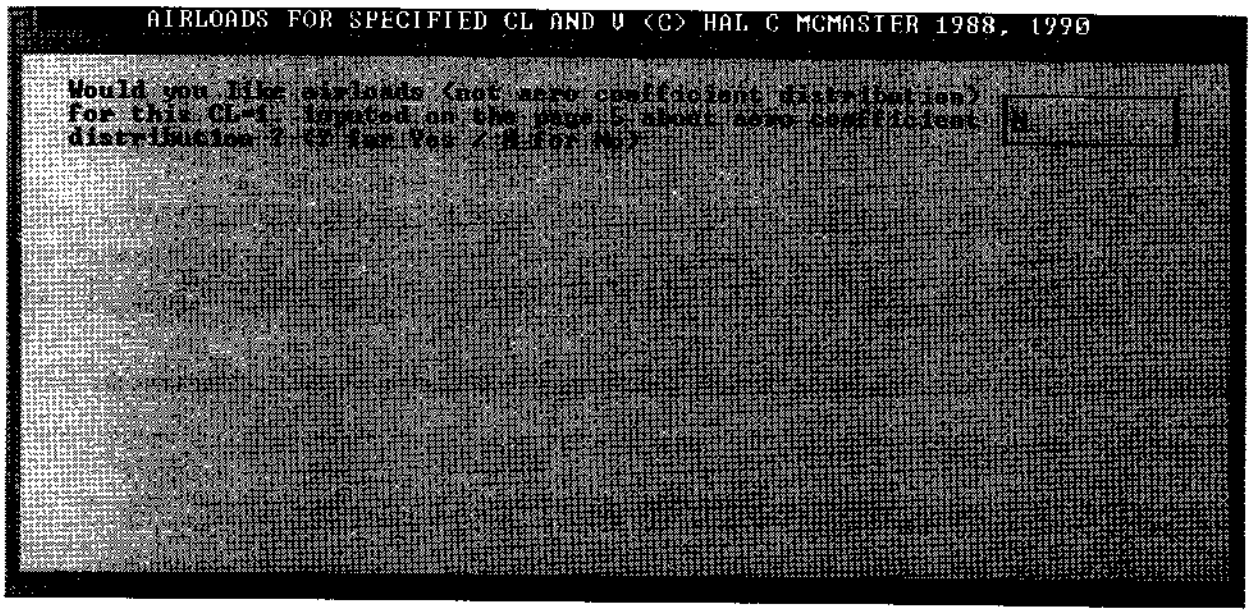

FIGURE 9.7a AIRLOADS SEVENTH INPUT WINDOW

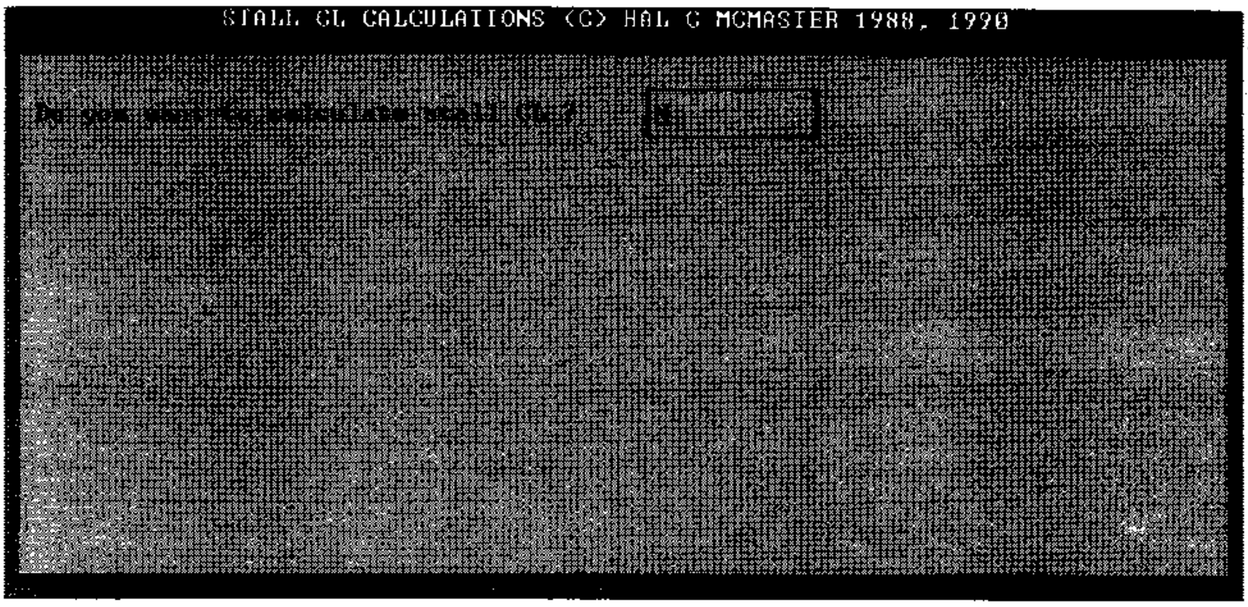

FIGURE 9.4b AIRLOADS ALTERNATE FOURTH INPUT WINDOW

On the fifth window, shown in figure 9.5, you will enter data for the spanwise drag and moment coefficients, C_D and C_M. You need to enter τ, which is a correction for the slope of the lift curve. The value for τ can be calculated on the ninth window, but then you will need to enter the value here.

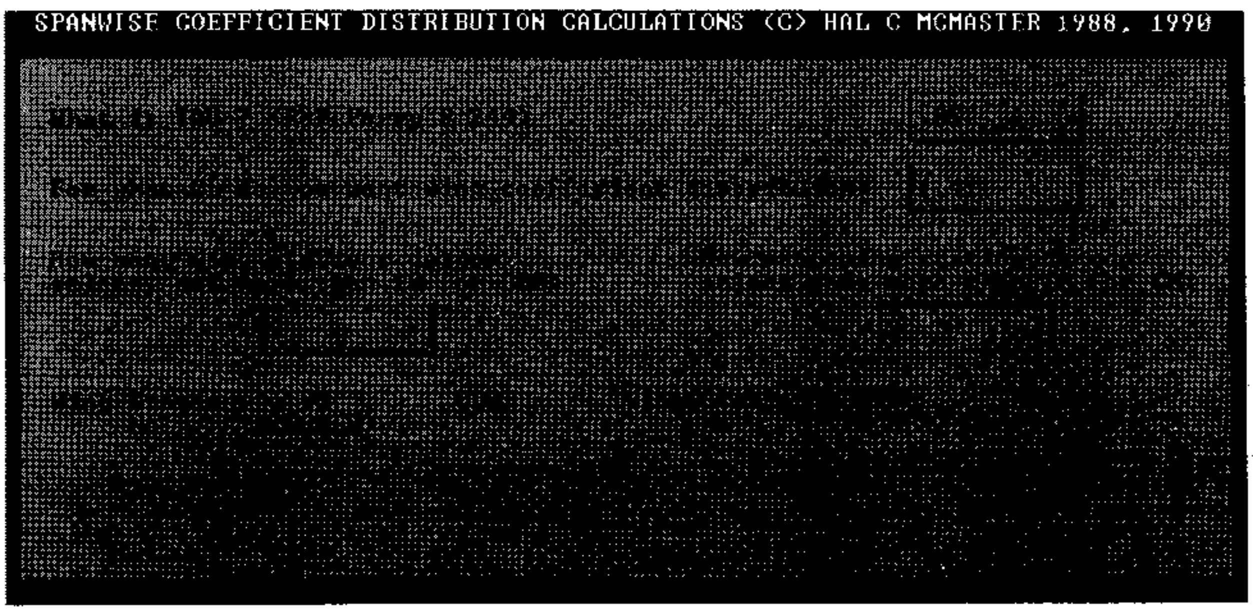

FIGURE 9.5 AIRLOADS FIFTH INPUT WINDOW

On the sixth screen, shown in figure 9.6, you will enter additional fuselage data.

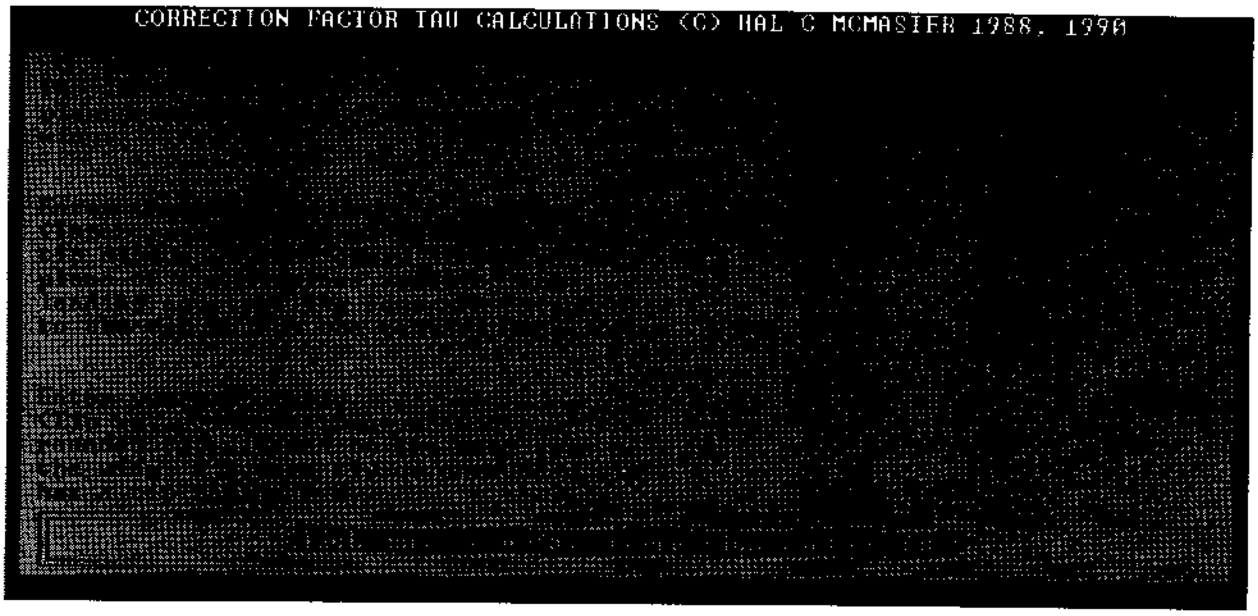

FIGURE 9.9a AIRLOADS NINTH INPUT WINDOW

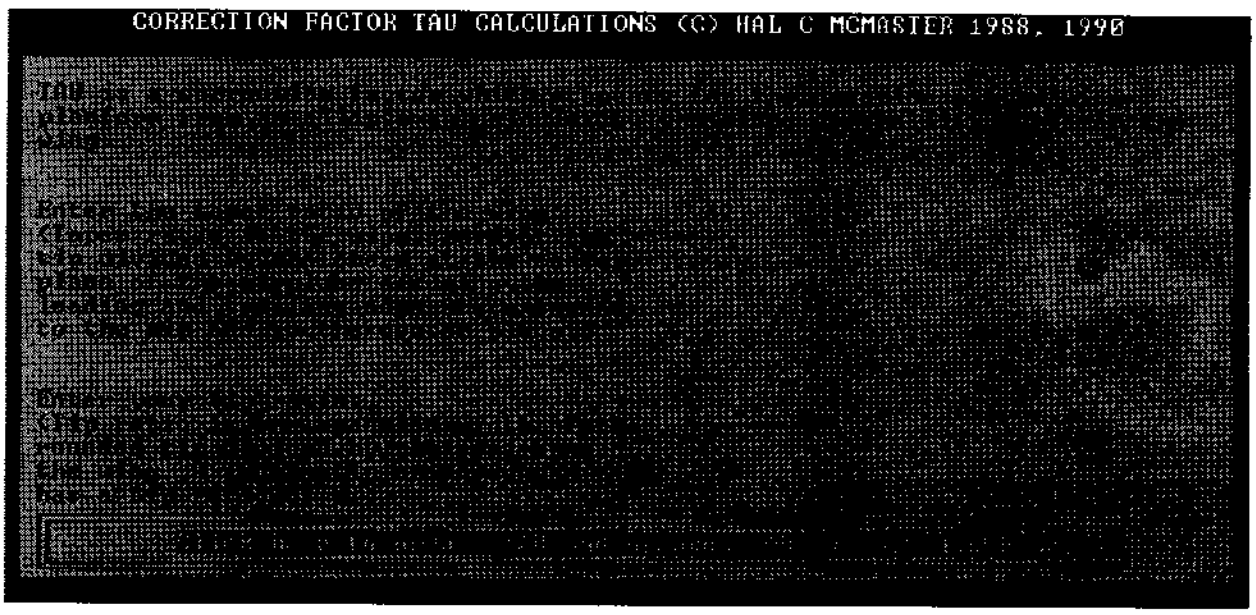

FIGURE 9.9b AIRLOADS NINTH INPUT WINDOW WITH TAU

9.3.2 Running the Analysis.

After all input data are entered in the input windows, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results; the first option saves the output to a file, and the second option prints the output.

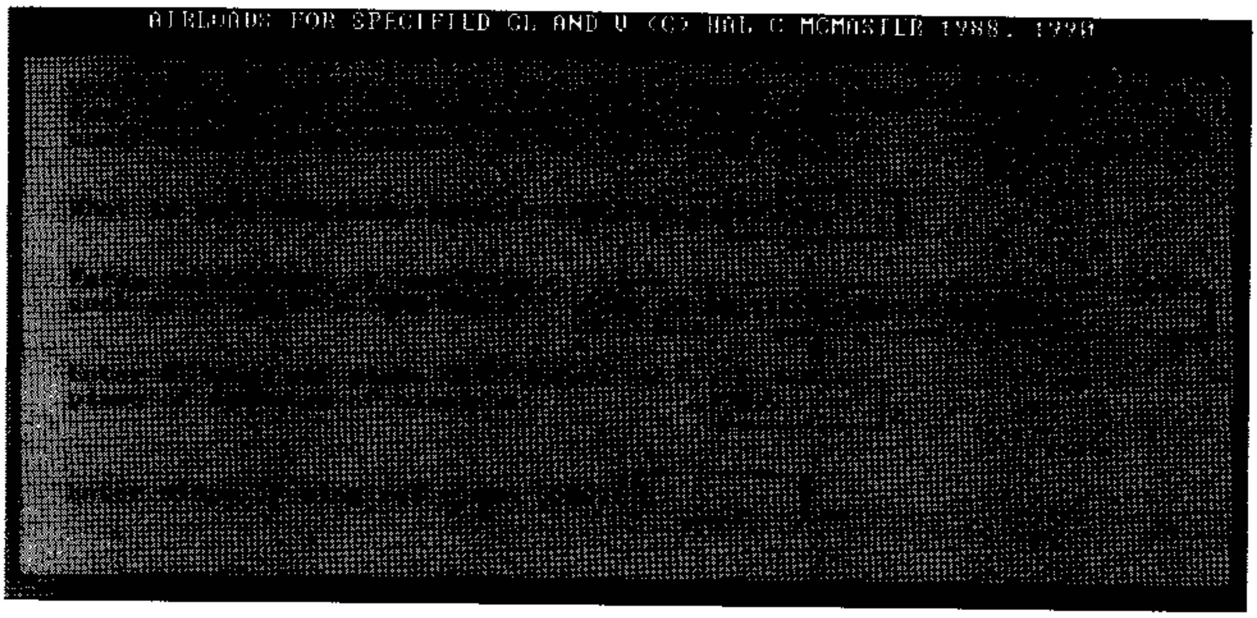

FIGURE 9.7b AIRLOADS ALTERNATE SEVENTH INPUT WINDOW

The data required to calculate the landing gear aerodynamic coefficients is entered on the eighth window shown in figure 9.8.

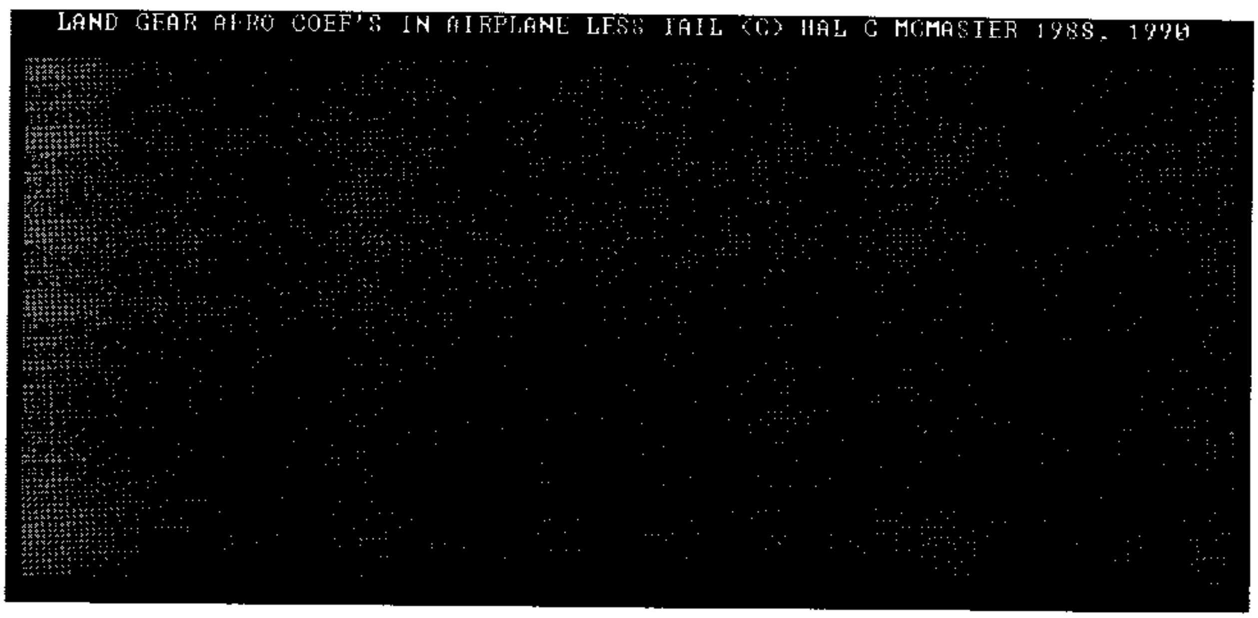

FIGURE 9.8 AIRLOADS EIGHTH INPUT WINDOW

The ninth window, shown in figure 9.9a, is used to calculate the correction factor tau (τ). To calculate τ, enter the data, then click on the bar at the bottom of the window. The value of τ will be displayed on this bar as shown in figure 9.9b.

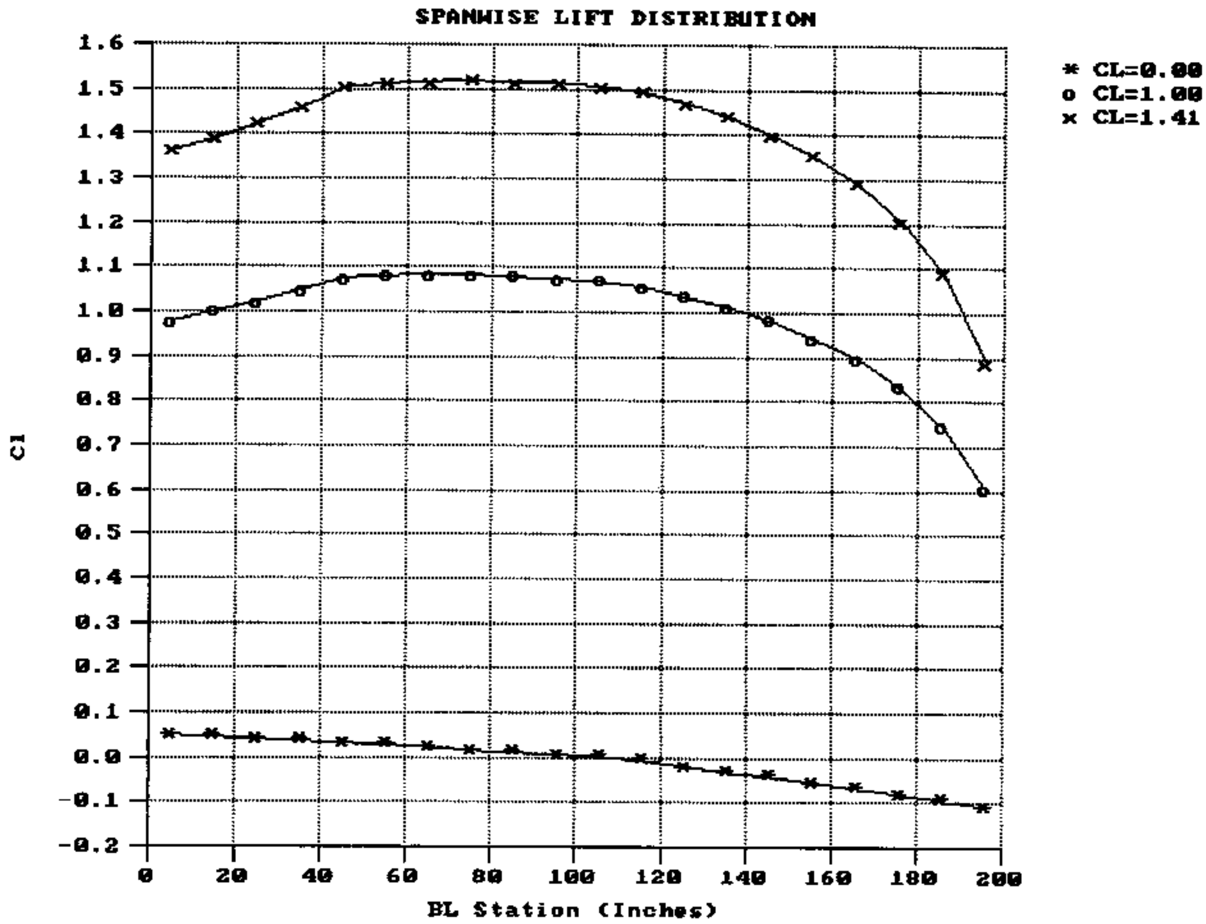

FIGURE 9.10 EXAMPLE OF LIFT DISTRIBUTION PLOT

9.4 AIRLOADS OUTPUT.

The AIRLOADS module produces the following:

- wing geometry calculations,
- additive lift distribution,
- basic lift distribution,
- stall calculations,
- wing aerodynamic coefficient distributions,
- airplane-less-tail aerodynamic coefficients, and
- equation for aerodynamic coefficients for airplane less tail.

The aerodynamic coefficients for the airplane less tail are used in FLTLOADS (section 11).

When calculating wing spanwise air loads, the output values are used by the program NETLOADS (section 16).

9.5 GRAPHICS.

The separate graphics program FAR23 Plot can be used to plot the aerodynamic coefficients. The FAR23 Plot program is described in the appendix of reference 1.

To plot the data, the output file from AIRLOADS or AIRLOAD4 must have a filename with the extension *.AIR*. An example of a plot is shown in figure 9.10.

calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and send the output data to a file or printer. *Return to Main Menu* exits from the AIRLOAD4 program and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The options Pg1 through Pg8 are for the eight input windows used to enter the data required for the analysis. Pg8 is appears only if landing gear data is required.

Except for the second and fifth windows, the input windows for AIRLOAD4 are the same as for AIRLOADS. Figures 10.2 and 10.3 show the second and fifth windows for AIRLOAD4. For the other windows see section 9.

Note: AIRLOAD4 does not need the ninth window for calculation of the correction factor τ; instead, the required data is entered on the fifth window (figure 10.3), and τ is calculated in the program.

On Pg6, you are asked if the landing gear is extended. If you answer Y, you should enter the data on Pg8. If you answer N, you do not need to enter landing gear data on Pg8 and this page will not appear in the options. Note that this is different from AIRLOADS since AIRLOADS always requires you to enter the data on Pg8.

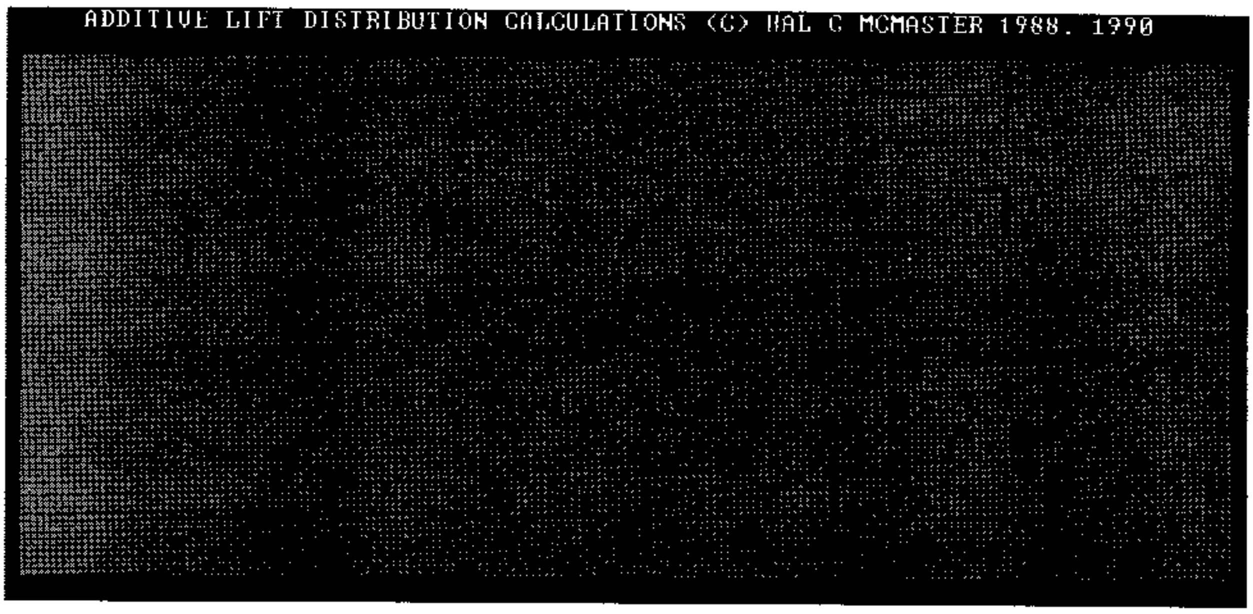

FIGURE 10.2 AIRLOAD4 SECOND INPUT WINDOW

10. ADDITIONAL AERODYNAMIC COEFFICIENTS AND AIRLOADS.

10.1 AIRLOAD4 DESCRIPTION.

The AIRLOADS (section 9) and AIRLOAD4 modules are similar in function. However, AIRLOAD4 is used to calculate the aerodynamic coefficients and loads if the sweepback of the 25% chord is greater than 15°. If the Mach number is greater than 0.5, then AIRLOAD4 must be used to calculate the air loads. Either AIRLOADS or AIRLOAD4 can be used to calculate the aerodynamic coefficients if the sweepback is less than 15°.

10.2 FAR 23 REGULATIONS.

The FAR 23 regulations for air loads are given in section 9.

10.3 RUNNING AIRLOAD4.

To run the module AIRLOAD4, select the button from the main menu window. The first input window will be displayed as shown in figure 10.1.

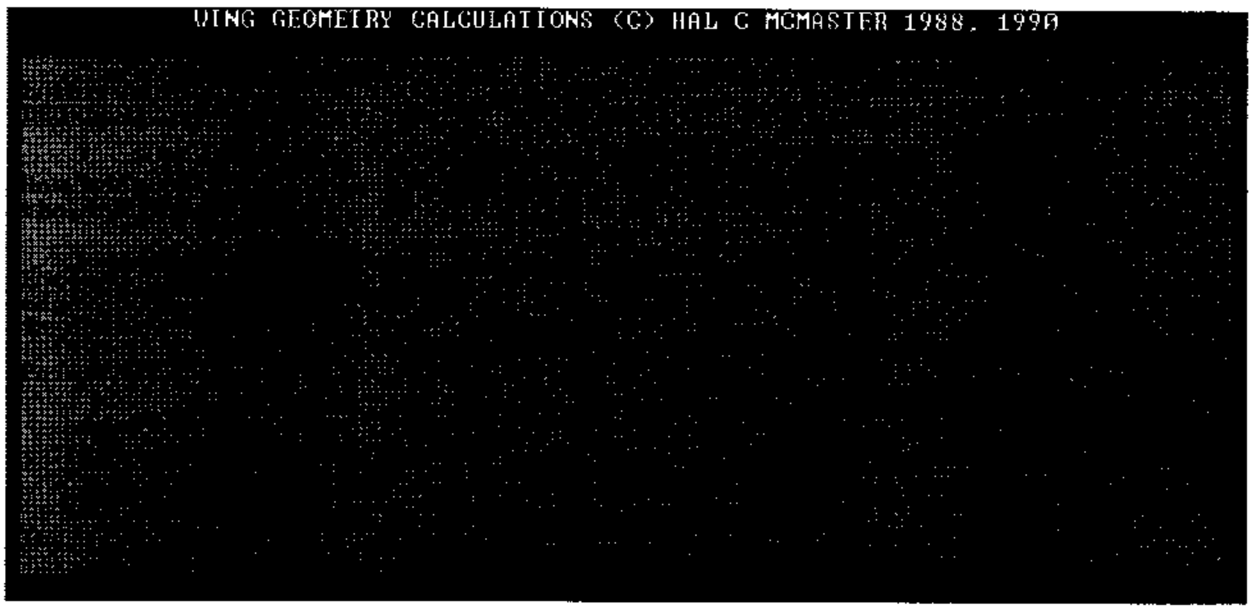

FIGURE 10.1 AIRLOAD4 FIRST INPUT WINDOW

10.3.1 Input Windows.

The first input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes ten or eleven menu options: File, Notepad, Color, and Pg1-8 or Pg1-8.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the

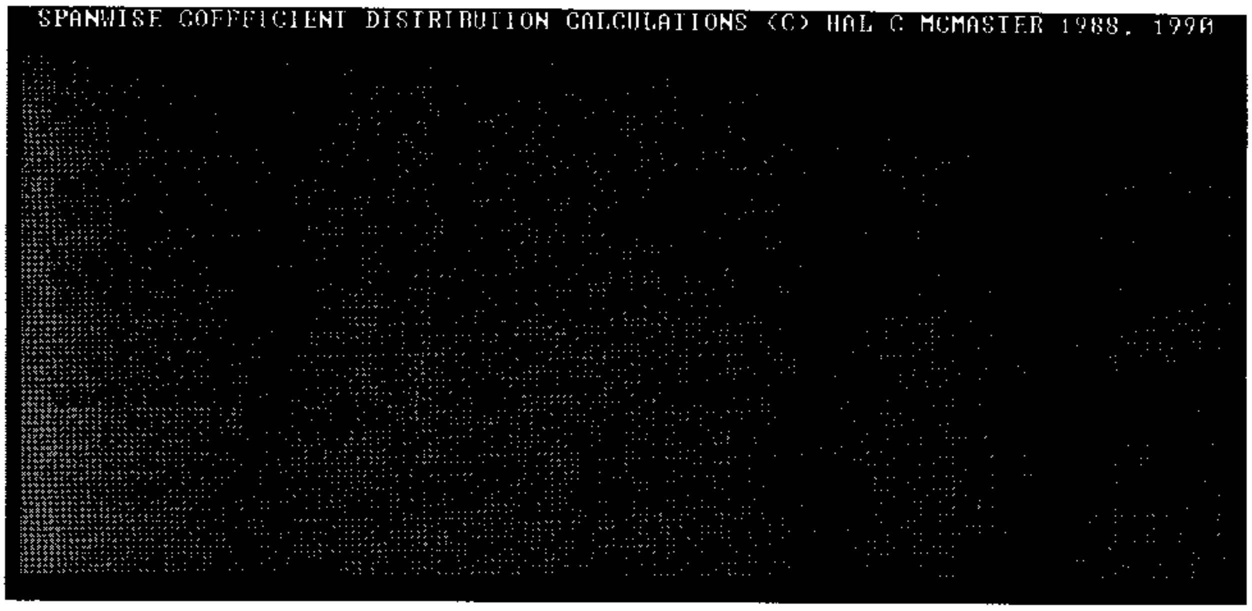

FIGURE 10.3 AIRLOAD4 FIFTH INPUT WINDOW

10.3.2 Running the Analysis.

After all inputs are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results; the first option saves the output to a file, and the second option prints the output.

10.4 AIRLOAD4 OUTPUT.

The output from AIRLOAD4 is similar to the output from AIRLOADS and is described in section 9.

10.5 GRAPHICS.

The separate graphics program FAR23 Plot can be used to plot the aerodynamic coefficients. The FAR23 Plot program is described in the appendix of reference 1.

To plot the data, the output file from AIRLOADS or AIRLOAD4 must have a filename with the extension *.AIR*. An example of a plot is shown in section 9.

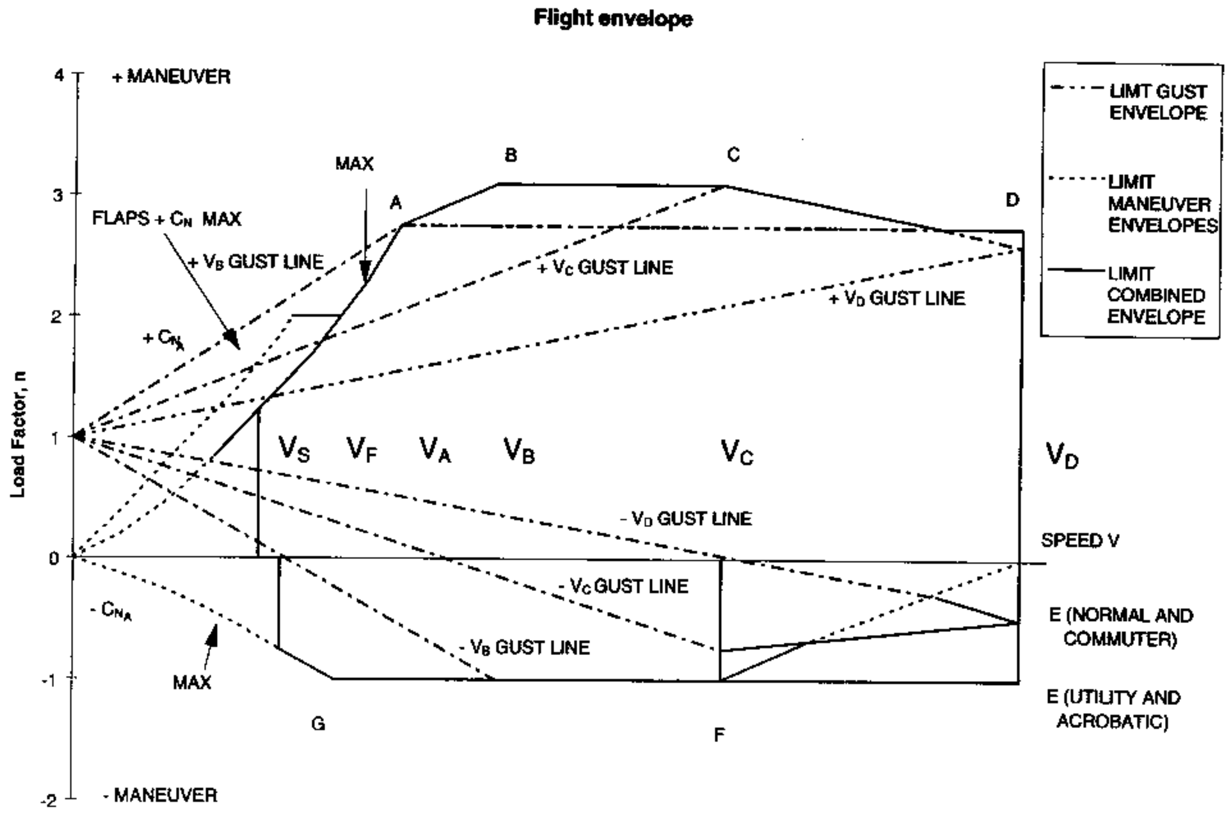

FIGURE 11.1 FLIGHT ENVELOPE FOR FAR 23.333(d)

11.2.1.3 Gust Envelope.

The airplane is assumed to be subjected to symmetrical vertical gusts in level flight. The resulting limit load factors must correspond to the conditions determined as follows:

a. Positive (up) and negative (down) gusts of 50 feet per second (fps) at V_C must be considered at altitudes between sea level and 20,000 feet. The gust velocity may be reduced linearly from 50 fps at 20,000 feet to 25 fps at 50,000 feet.

b. Positive and negative gusts of 25 fps at V_D must be considered at altitudes between sea level and 20,000 feet. The gust velocity may be reduced linearly from 25 fps at 20,000 feet to 12.5 fps at 50,000 feet.

c. In addition, for commuter category airplanes, positive (up) and negative (down) rough air gusts of 66 fps at V_B must be considered at altitudes between sea level and 20,000 feet. The gust velocity may be reduced linearly from 66 fps at 20,000 feet to 38 fps at 50,000 feet.

11. FLIGHT ENVELOPE.

11.1 FLTLOADS DESCRIPTION.

The FLTLOADS module calculates the loads for any combination of airspeed and load factor on and within the boundaries of the flight envelope. The flight envelope is defined in FARs 23.333, 23.345, and 23.373. The data necessary to make these load calculations comes from the results of modules WTENV (section 5), WINGGEOM (section 6), STRSPEED (section 7), and AIRLOADS or AIRLOAD4 (sections 9 and 10).

The flight envelope should be developed for altitudes up to the maximum operating altitude. For airplanes with a maximum operating altitude less than 20,000 feet, three altitudes are usually used: sea level, shoulder altitude, and maximum operating altitude. If the maximum operating altitude is greater than 20,000 feet, then 20,000 feet should be included since this is where the gust formulas begin to taper.

The flight envelope with flaps extended for takeoff, approach, and landing needs to be determined at sea level only.

11.2 FAR 23 REGULATIONS.

FAR 23.333 defines the flight envelope for maneuver and gust for normal, utility, and acrobatic category airplanes. The envelope for high lift devices (flaps) is defined in FAR 23.345 and for speed control devices in FAR 23.373.

11.2.1 FAR 23.333 Flight Envelope.

11.2.1.1 General.

Compliance with the strength requirements of this subpart must be shown at any combination of airspeed and load factor on and within the boundaries of a flight envelope (similar to the one shown in figure 11.1) which represents the envelope of the flight loading conditions specified by the maneuvering and gust criteria of sections 11.2.1.2 and 11.2.1.3.

11.2.1.2 Maneuvering Envelope.

Except where limited by maximum (static) lift coefficients, the airplane is assumed to be subjected to symmetrical maneuvers resulting in the following limit load factors:

a. The positive maneuvering load factor specified in FAR 23.337 at speeds up to V_D.

b. The negative maneuvering load factor specified in FAR 23.337 at V_C.

c. Factors varying linearly with speed from the specified value at V_C to 0.0 at V_D for the normal and commuter category and -1.0 at V_D for the acrobatic and utility categories.

11.2.3 FAR 23.373 Speed Control Devices.

If speed control devices (such as spoilers and drag flaps) are incorporated for use in enroute conditions

a. the airplane must be designed for the symmetrical maneuvers and gusts prescribed in FARs 23.333, 23.337, and 23.341 and the yawing maneuvers and lateral gusts in FARs 23.441 and 23.443 with the device extended at speeds up to the placard device extended speed; and

b. if the device has automatic operating or load limiting features, the airplane must be designed for the maneuver and gust conditions prescribed in the previous bullet of this section at the speeds and corresponding device positions that the mechanism allows.

11.3 RUNNING FLTLOADS.

To run FLTLOADS, select the button from the main menu window. The first input window will be displayed as shown in figure 11.2.

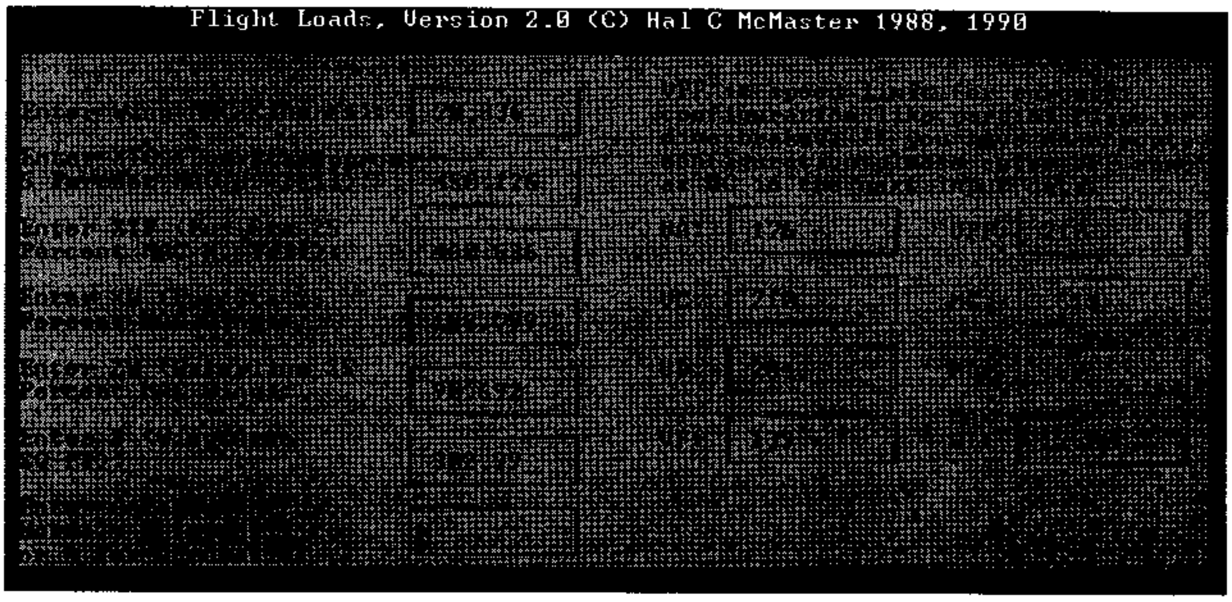

FIGURE 11.2 FLTLOADS FIRST INPUT WINDOW

11.3.1 Input Windows.

The first input window is displayed when the module starts. This window also includes eleven menu options: File, Notepad, Color, and Pg1-Pg8.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As Report Format* will perform the calculations and save the output file in report format. *Save Output As Format*

The following assumptions are made:

a. The shape of the gust is

$$U = \frac{U_{de}}{2}\left(1 - \cos\frac{2\pi s}{25C}\right)$$

where

s = distance penetrated into gust (ft),
C = mean geometric chord of wing (ft), and
U_{de} = derived gust velocity referred to in subparagraph a. of this section.

b. Gust load factors vary linearly with speed between V_C and V_D.

11.2.2 FAR 23.345 High Lift Devices.

If flaps or similar high lift devices to be used for takeoff, approach, or landing are installed, the airplane, with the flaps fully deflected at V_F, is assumed to be subjected to symmetrical maneuvers and gusts resulting in limit load factors within the range determined by

a. maneuvering to a positive limit load factor of 2.0 and
b. positive and negative gust of 25 fps acting normal to the flight path in level flight.

V_F must be assumed to be not less than 1.4 V_S or 1.8 V_{SF}, whichever is greater, where

a. V_S is the computed stalling speed with flaps retracted at the design weight, and
b. V_{SF} is the computed stalling speed with flaps fully extended at the design weight.

However, if an automatic flap load limiting device is used, the airplane may be designed for the critical combinations of airspeed and flap position allowed by that device.

In designing the flaps and supporting structures, the following must be accounted for:

a. A head-on gust having a velocity of 25 fps (EAS).
b. The slipstream effects specified in FAR 23.457(b).

In determining external loads on the airplane as a whole, thrust, slipstream, and pitching acceleration may be assumed to be zero.

The requirements of FAR 23.457 and this section may be complied with separately or in combination.

You can enter up to four loading c.g. conditions. The required data includes a description, weight and c.g. coordinates. This information comes from WTONECG (section 4).

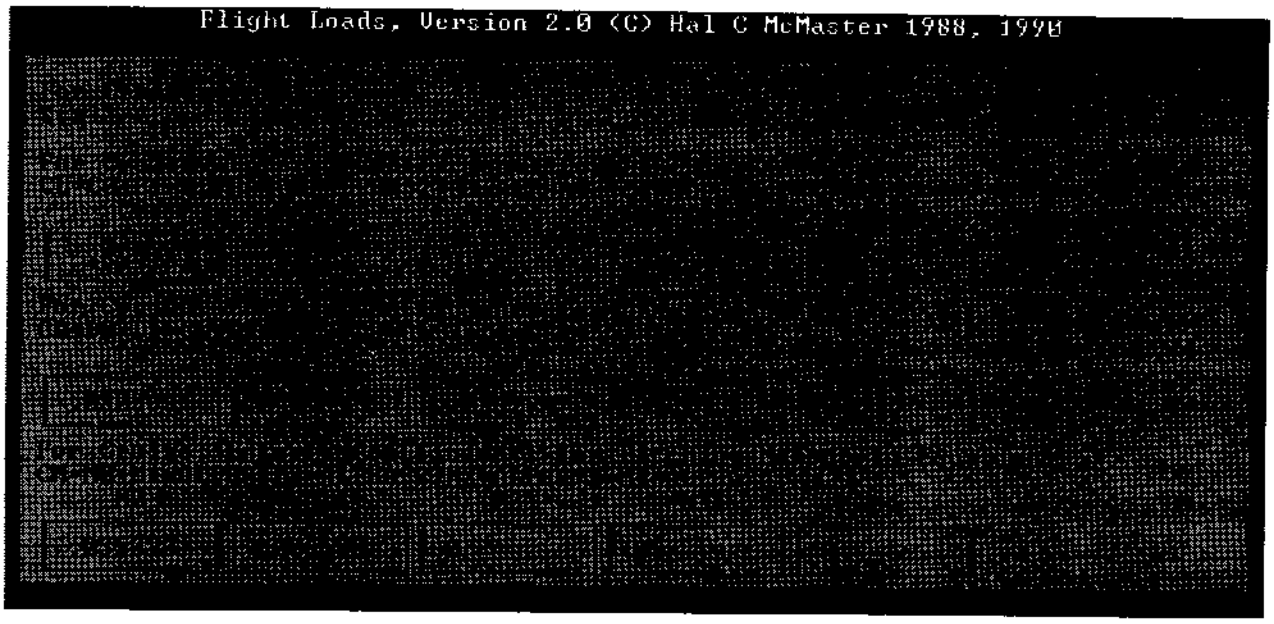

FIGURE 11.4 FLTLOADS THIRD INPUT WINDOW

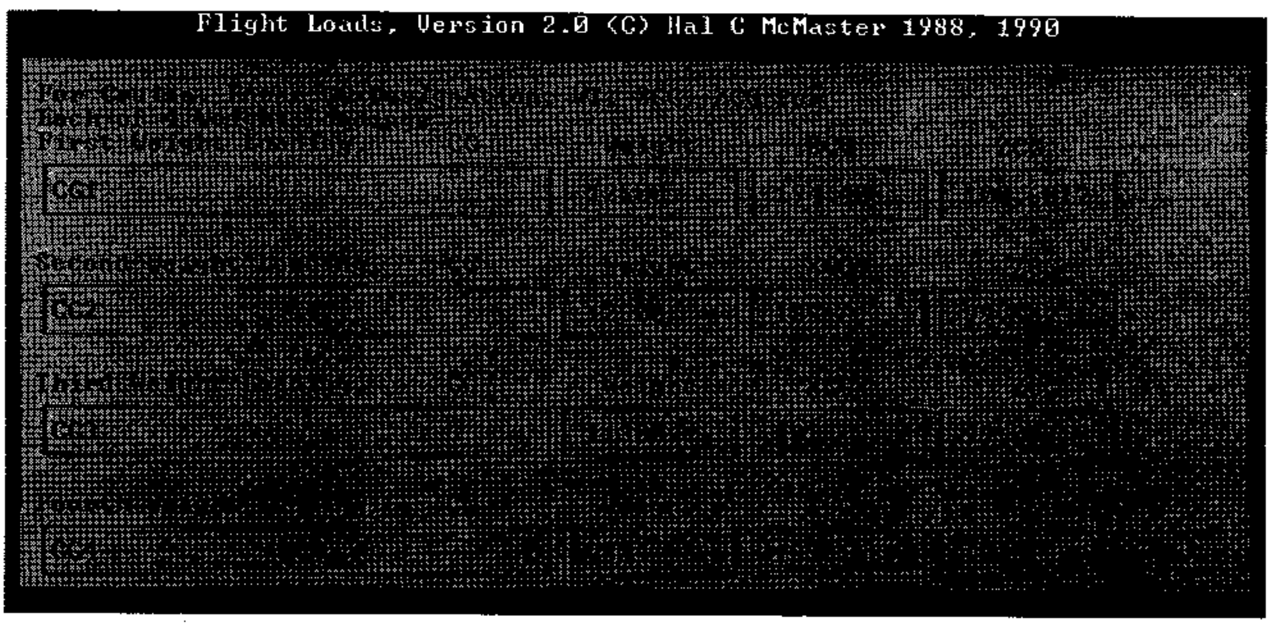

FIGURE 11.5 FLTLOADS FOURTH INPUT WINDOW

SELECT Required will perform the calculations and save the output file in the format required by SELECT (described in section 12). *Print Input* allows you to print only the input data. *Print Output* allows you to perform the calculations and send the output data to a file or printer. *Return to Main Menu* exits from FLTLOADS and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The eight different input windows are accessed with the Pg1, Pg2, etc., menu items. The data required for input windows Pg1 and Pg2 is general data such as airplane category, geometric data, and speeds. These windows are shown in figures 11.2 and 11.3, respectively. The speeds are entered in KEAS, the coordinates are in inches, and the area is in ft^2.

On the first input window, you enter the category of the airplane, either normal, utility, or acrobatic. This category determines the minimum required load factor on the second window as shown in figure 11.3.

On Pg2, you will be asked if you have an enroute condition. If not, then the question about flaps for enroute will not appear, and you will not see the input windows for enroute (Pg7 and Pg8). Also, on the first window (Pg1) where you enter VPF, use V_C if you have an enroute condition.

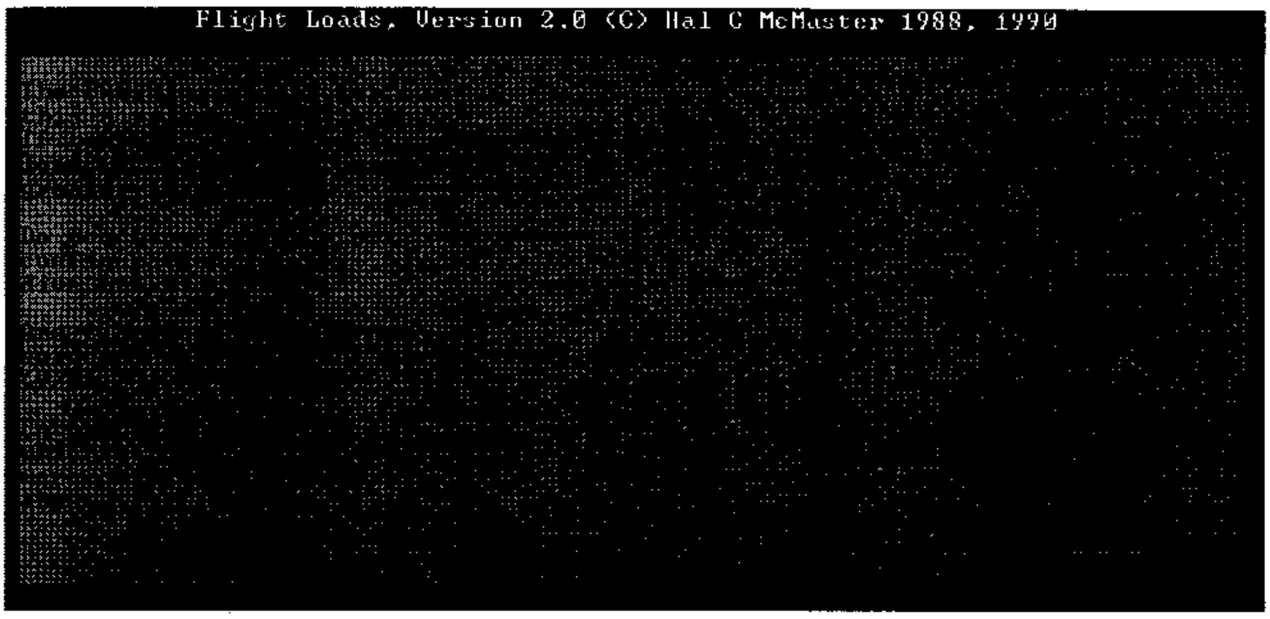

FIGURE 11.3 FLTLOADS SECOND INPUT WINDOW

The input windows, designated Pg3 through Pg8 and shown in figures 11.4 through 11.9, are used to enter data for cruise, landing, and enroute configurations. Each configuration requires two input windows; where the first window asks for the coefficients for the lift (C_0, C_1, C_2, C_3, and C_4), drag (D_0, D_1, D_2, D_3, and D_4), and pitching moment (M_0, M_1, M_2, M_3, and M_4) equations, and the second window asks for the loading c.g. data.

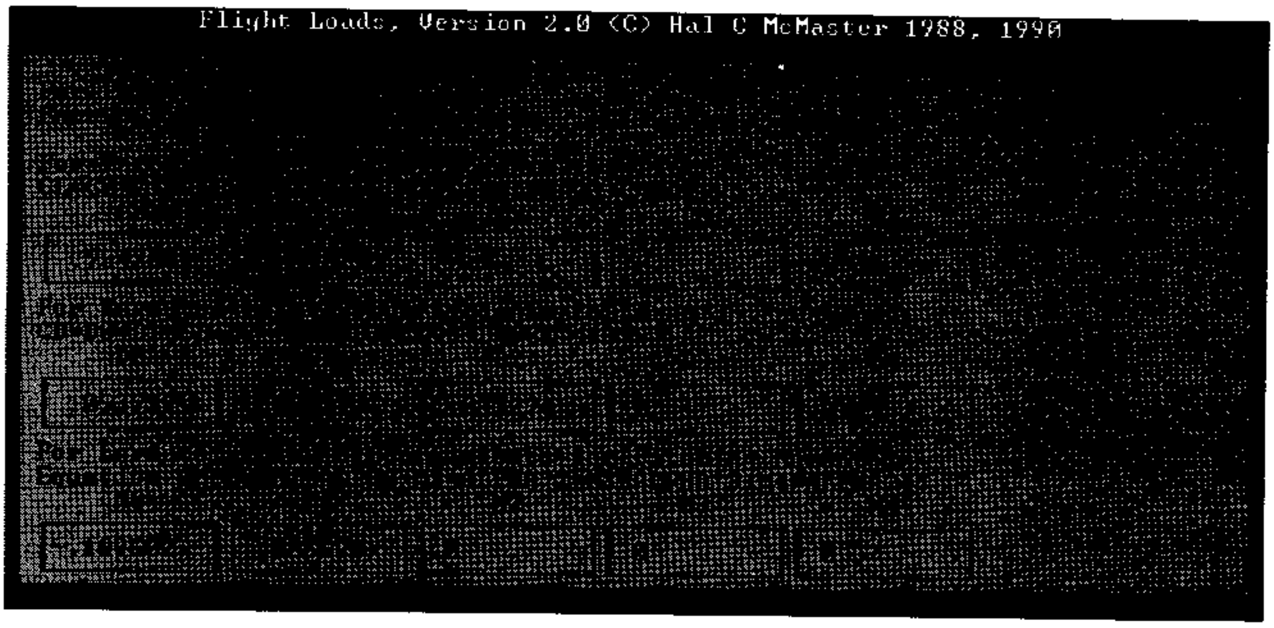

FIGURE 11.8 FLTLOADS SEVENTH INPUT WINDOW

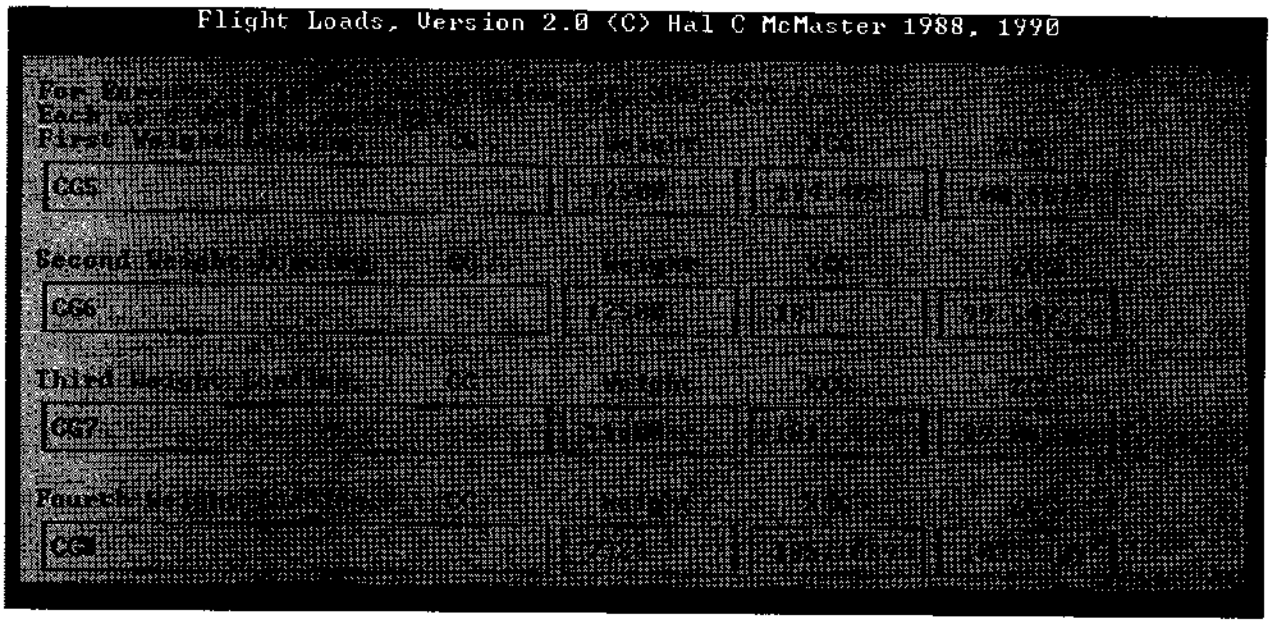

FIGURE 11.9 FLTLOADS EIGHTH INPUT WINDOW

The data necessary to make these load calculations comes from the results of the modules WTONECG (section 4), WTENV (section 5), WINGGEOM (section 6), STRSPEED (section 7), and AIRLOADS or AIRLOAD4 (section 9 or section 10).

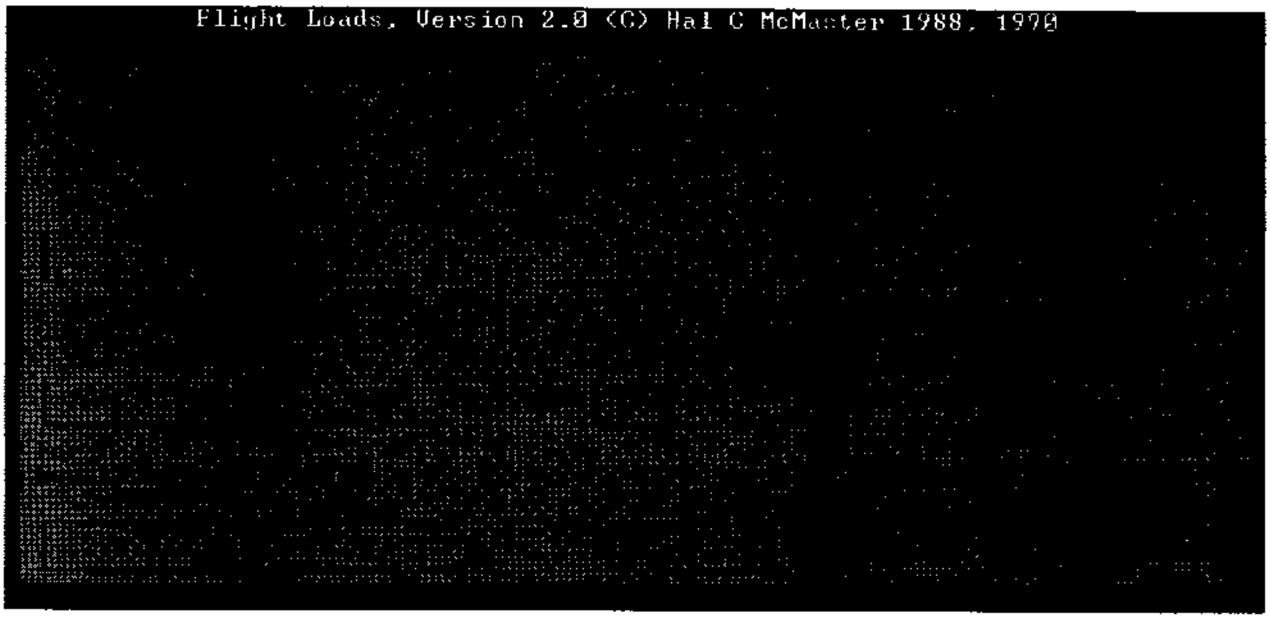

FIGURE 11.6 FLTLOADS FIFTH INPUT WINDOW

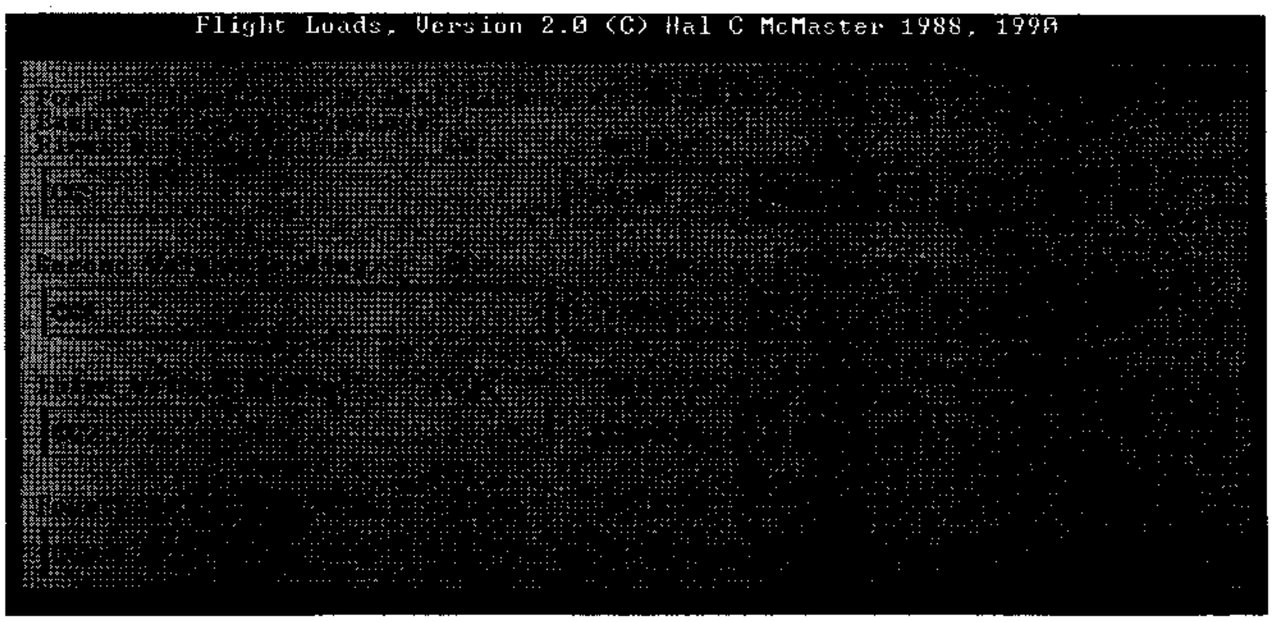

FIGURE 11.7 FLTLOADS SIXTH INPUT WINDOW

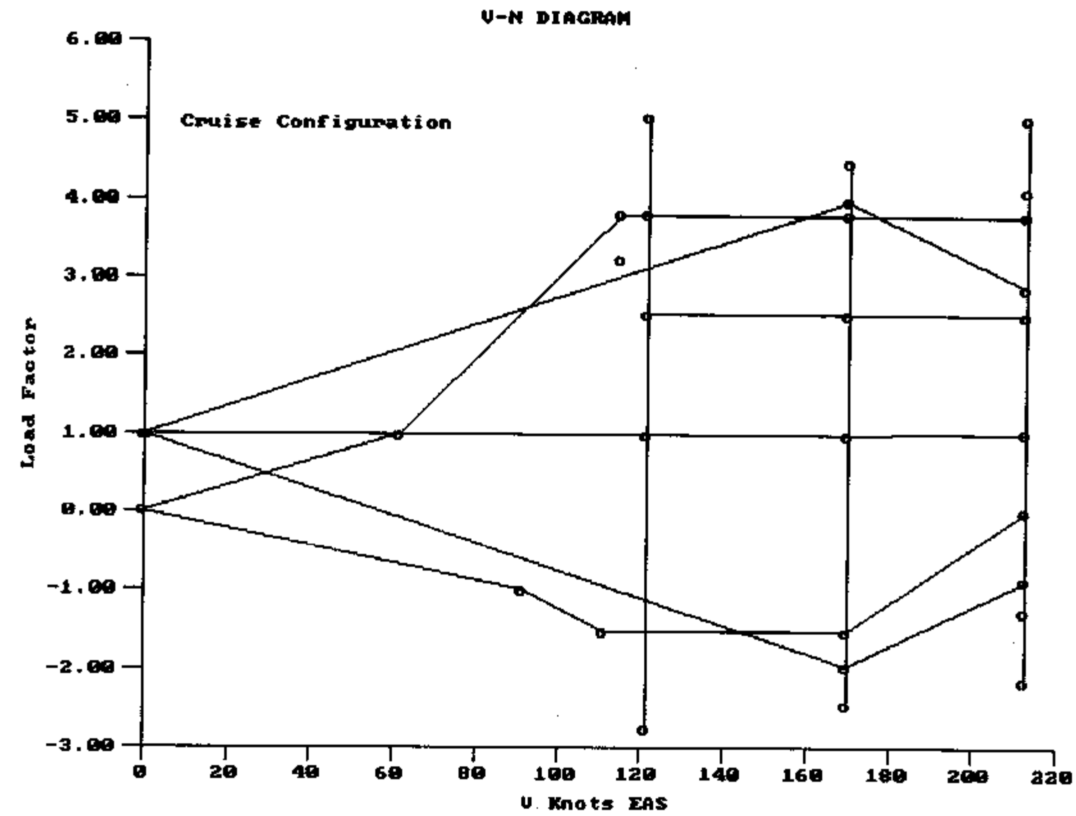

FIGURE 11.10 EXAMPLE OF A FLIGHT ENVELOPE

11.3.2 Running the Analysis.

After all inputs are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As Report Format, Save Output As Format SELECT Required,* or *Print Output*. Any of these selections will calculate the results, but you will need to select more than one option to get the output in more than one the format. If you want to use the results in SELECT (section 12), you need to select the option to save results in the correct format. If you want to save the data to a file and print it, you will need to select those options also.

11.4 FLTLOADS OUTPUT.

The output from FLTLOADS is used in SELECT (section 12) and WINGINER (section 15). The data for each point on the flight envelope is included in the output file. The following data is included, and if applicable, the variable name used in the output file is given:

- name of the condition and case number,
- altitude (feet) and equivalent air speed (knots),
- normal load factor n_z,
- angle of attack α (degrees),
- compressibility factor (variable G CORR),
- wing lift coefficient C_L,
- pitching moment of airplane less tail (variable M(W+F)),
- wing lift normal to the airplane reference line (lbs) (variable LZW),
- tail load (lbs) (variable LT), and
- airplane drag load (lbs) (variable DX).

11.5 GRAPHICS.

The separate graphics program FAR23 Plot can be used to draw the flight envelope. The FAR23 Plot program is described in the appendix of reference 1.

To plot the results, the output file from FLTLOADS must have a filename with the extension *.LDS*. An example of a flight envelope is shown in figure 11.10.

critical for fuselage vertical shear forward of the wing forward attachment. The V-n data is searched for the largest wing upload accounting for relieving wing inertia. For aft fuselage mounted engines, this condition could also be critical for aft fuselage bending.

The loading on the aft fuselage is critical for down bending due to unchecked pullup maneuver and due to the combination of down tail load and down fuselage inertia in balanced flight conditions. Also, the largest up bending from the combination of up tail load and up fuselage inertia in balanced flight condition is the critical loading for the aft fuselage.

The loading on the forward fuselage is usually critical for the same condition as the maximum aft fuselage down bending and up bending.

Accelerated pitching due to maneuver or gust may produce the critical loading in the aft fuselage. These conditions are determined in the tail section.

12.1.3 Horizontal Tail Loads.

The tail surface loads are reactions to the airplane air and inertia loads and the pitching and yawing motions and are functions of the angle of attack and camber due to control surface deflections. Lift acts at the 0.25 chord due to the change in angle of attack and at about the 50% chord due to the change in camber.

The rational tail loads are calculated per Amendment 42. First, the downwash at the tail is calculated as

$$\varepsilon = \frac{114.6 C_{L-w}}{\pi A R_w}$$

where:

ε = downwash at the tail
C_{L-w} = lift coefficient of the wing
AR_w = aspect ratio of the wing

Then the angle of attack (figure 12.1) of the stabilizer is calculated

$$\alpha_t = \alpha_{wing} - i_w + i_t - \varepsilon$$

where:

α_t = absolute angle of attack at the tail
α_{wing} = angle of attack of wing, relative wind line to zero lift line of wing
i_w = incidence of wing, angle from waterline to zero lift line of wing
i_t = incidence of tail, angle from waterline to zero lift line of tail
ε = downwash, relative wind line of wing to relative wind line of tail

12. SELECTION OF CRITICAL LOADS.

12.1 SELECT DESCRIPTION.

The critical flight loads are determined by SELECT using the results of FLTLOADS. The output file from FLTLOADS contains all the balanced symmetrical flight conditions on the V-n diagram. SELECT searches this file for the critical flight loads on the wing, fuselage, horizontal tail, and vertical tail. Critical loads for the other structures such as ailerons, flaps, engine mounts, landing gear, and tabs are determined in other modules as explained in sections 13, 14, 17, 18, and 21, respectively.

In addition to the flight envelope data, additional geometry and inertia data from WTONECG (section 4) and WINGGEOM (section 6) are required.

12.1.1 Wing Loads.

The V-n data is searched for the largest net load on the wing for the following conditions:

- positive maneuver load factor at V_A ,
- positive maneuver load factor at V_C ,
- negative maneuver load factor at V_C ,
- positive maneuver load factor at V_D ,
- positive gust load at V_C,
- negative gust load at V_C,
- accelerated roll condition producing the largest resultant air load on the wing at V_A, and
- steady roll conditions required by FAR 23.349(b) at speeds V_A, V_C, and V_D for the maximum wing torsion produced by the aileron.

12.1.2 Fuselage Loads.

The fuselage loads are not specifically addressed in the FAR 23 regulations, but they are implied in the regulations for the tail and wing. The local loads from the tail are discussed in the following sections on tail loads. The engine mount loads are discussed in section 17, and the landing loads are discussed in section 18.

The V-n data is searched for all the balanced symmetrical conditions, including maneuver and gust conditions, for the critical balanced loads.

The flight loads on the fuselage are critical for vertical shear loading aft of and adjacent to the rear spar attachment resulting from the maximum net upload on the wing. They may also be

Maneuvering tail loads are determined for the checked and unchecked pullup maneuvers and checked and unchecked push-down maneuvers. The unchecked pullup and push-down maneuver tail loads are calculated at every 1 g balanced point at V_A on all the V-n diagrams. The total load, due to angle of attack at the 25% chord, due to camber at the 50% chord, and the deflection of the elevator are calculated.

The up and down gust tail loads are determined for flaps retracted and flaps extended as specified in FAR 23.425. Unsymmetrical tail loads are determined per FAR 23.427.

12.1.4 Vertical Tail Loads.

The vertical tail loads required in FARs 23.441(a) and 23.443(b) are calculated using the rational loads method. These loads include

- vertical tail side load for sudden displacement to the maximum rudder deflection at V_A with the airplane in unaccelerated flight at zero yaw,
- vertical side tail load for rudder deflected to full deflection and airplane yawed to a sideslip angle of 19.5°,
- vertical side tail load for yaw angle of 15° with the rudder control maintained in the neutral position, and
- lateral gust load in unaccelerated flight at V_C.

12.2 FAR 23 REGULATIONS.

The regulations for loads are defined in FARs 23.301, 23.321, 23.331, and 23.349 and repeated here for convenience.

12.2.1 FAR 23.301 Loads (General).

a. Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

b. Unless otherwise provided, the air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the airplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution on canard and tandem wing configurations must be validated by flight test measurement unless the methods used for determining those loading conditions are shown to be reliable or conservative on the configuration under consideration.

c. If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

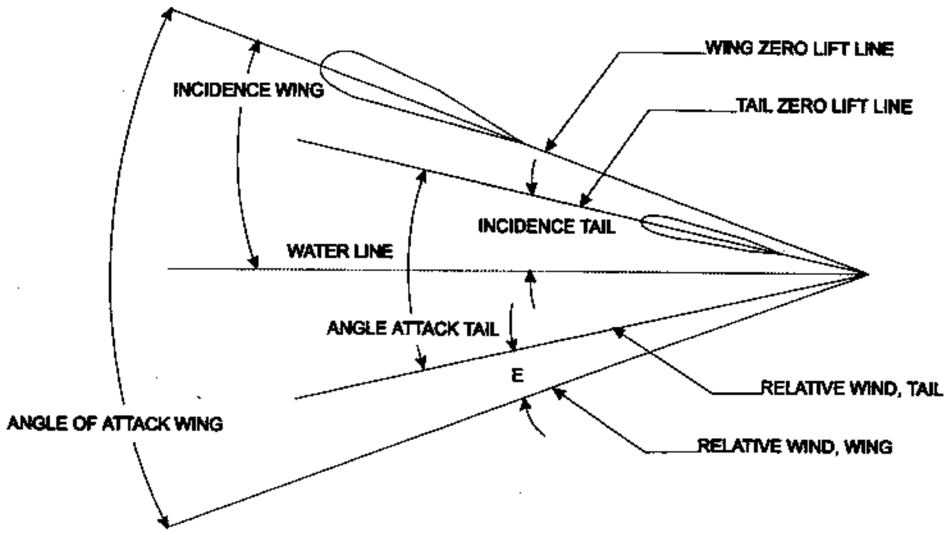

FIGURE 12.1 GEOMETRIC RELATION BETWEEN ANGLE OF ATTACK OF WING AND TAIL

The load due to the angle of attack at the 25% chord of the tail is

$$L_t = \left(\frac{\Delta C_{L-t}}{\Delta\alpha x \alpha}\right) q\, S_t$$

where:

L_t = load at the 25% chord of the tail
ΔC_{L-t} = change in lift coefficient of the tail
α = angle of attack of the tail
$\Delta\alpha$ = change in angle of attack
q = dynamic pressure
S_t = surface area of the tail

The airplane is balanced about the c.g. to find the lift due to camber at the 50% chord of the tail and the deflection of the elevator. The chordwise distribution from the angle of attack load is the average pressure at the quarter chord, zero at the trailing edge, and four times the average pressure at the leading edge. The chordwise distribution of the camber load at the 50% chord is trapezoidal, which is symmetrical about the 50% chord with zero load at the trailing edge to w at the hinge line. Then the net chordwise distribution is the algebraic sum of the chordwise distributions.

The largest positive and negative balancing tail loads are determined from the V-n data for both flaps extended and flaps retracted conditions. After selecting the critical balanced conditions, the load due to angle of attack at the 25% chord, the load due to camber at the 50% chord, the deflection of the elevator, and the elevator load are determined.

(1) For the acrobatic category, in conditions A and F, assume that 100 percent of the semispan wing air load acts on one side of the plane of symmetry and 60 percent of this load acts on the other side.

(2) For normal, utility, and commuter categories, in Condition A, assume that 100 percent of the semispan wing air load acts on one side of the airplane, and 70 percent of this load acts on the other side. For airplanes of more than 1,000 pounds design weight, the latter percentage may be increased linearly with weight up through 75 percent at 12,500 pounds to the maximum gross weight of the airplane.

b. The wing and wing bracing must be designed for loads resulting from the aileron deflections and speeds specified in FAR 23.455, in combination with an airplane load factor of at least two thirds of the positive maneuvering load factor used for design. Unless the following values result in unrealistic loads, the effect of aileron displacement on wing torsion may be accounted for by adding the following increment to the basic airfoil moment coefficient over the aileron portion of the span in the critical condition determined in FAR 23.333(d):

$$\Delta C_m = -0.01\delta$$

where:

ΔC_m is the moment coefficient increment, and
δ is the down aileron deflection in degrees in the critical condition.

12.2.5 FAR 23.351 Yawing Conditions.

The airplane must be designed for yawing loads on the vertical surfaces resulting from the loads specified in FARs 23.441 through 23.445.

12.2.6 FAR 23.421 Balancing Loads (Horizontal Tail).

a. A horizontal surface balancing load is a load necessary to maintain equilibrium in any specified flight condition with no pitching acceleration.

b. Horizontal balancing surfaces must be designed for the balancing loads occurring at any point on the limit maneuvering envelope and in the flap conditions specified in FAR 23.345.

12.2.7 FAR 23.423 Maneuvering Loads (Horizontal Tail).

Each horizontal surface and its supporting structure and the main wing of a canard or tandem wing configuration, if that surface has pitch control, must be designed for the maneuvering loads imposed by the following conditions:

d. Simplified structural design criteria may be used if they result in design loads not less than those prescribed in FARs 23.331 through 23.521. For conventional, single-engine airplanes with design weights of 6,000 pounds or less, the design criteria of Appendix A of this part are an approved equivalent of FARs 23.321 through 23.459. If Appendix A is used, the entire appendix must be substituted for the corresponding sections of this part.

12.2.2 FAR 23.321 General (Flight Loads).

a. Flight load factors represent the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the airplane) to the weight of the airplane. A positive flight load factor is one in which the aerodynamic force acts upward with respect to the airplane.

b. Compliance with the flight load requirements of this subpart must be shown

   (1) at each critical altitude within the range in which the airplane may be expected to operate,

   (2) at each weight from the design minimum weight to the design maximum weight, and

   (3) for each required altitude and weight and for any practicable distribution of disposable load within the operating limitations specified in FARs 23.1583 through 23.1589.

c. When significant, the effects of compressibility must be taken into account.

12.2.3 FAR 23.331 Symmetrical Flight Conditions.

a. The appropriate balancing horizontal tail load must be accounted for in a rational or conservative manner when determining the wing loads and linear inertia loads corresponding to any of the symmetrical flight conditions specified in FARs 23.333 through 23.341.

b. The incremental horizontal tail loads due to maneuvering and gusts must be reacted by the angular inertia of the airplane in a rational or conservative manner.

c. Mutual influence of the aerodynamic surfaces must be taken into account when determining flight loads.

12.2.4 FAR 23.349 Rolling Conditions.

The wing and wing bracing must be designed for the following loading conditions:

a. Unsymmetrical wing loads appropriate to the category. Unless the following values result in unrealistic loads, the rolling accelerations may be obtained by modifying the symmetrical flight conditions in FAR 23.333(d) as follows:

d. In the absence of a more rational analysis, the incremental load due to the gust must be computed as follows only on airplane configurations with aft-mounted, horizontal surfaces, unless its use elsewhere is shown to be conservative:

$$\Delta L_{ht} = \frac{K_g U_{de} V a_{ht} S_{ht}}{498}\left(1 - \frac{d\varepsilon}{d\alpha}\right)$$

where:

ΔL_{ht} = Incremental horizontal tail load (lb),
K_g = Gust alleviation factor defined in FAR 23.341,
U_{de} = Derived gust velocity (fps),
V = Airplane equivalent speed (knots),
a_{ht} = Slope of aft horizontal lift curve (per radian),
S_{ht} = Area of aft horizontal lift surface (ft^2), and
$\left(1 - \frac{d\varepsilon}{d\alpha}\right)$ = Downwash factor

12.2.9 FAR 23.427 Unsymmetrical Tail Loads (Horizontal Tail).

a. Horizontal surfaces other than main wing and their supporting structure must be designed for unsymmetrical loads arising from yawing and slipstream effects in combination with the loads prescribed for the flight conditions set forth in FARs 23.421 through 23.425.

b. In the absence of more rational data for airplanes that are conventional in regard to location of engines, wings, horizontal surfaces other than main wing, and fuselage shape,

(1) 100 percent of the maximum loading from the symmetrical flight conditions may be assumed on the surface on one side of the plane symmetry, and

(2) the following percentage of that loading must be applied to the opposite side:

Percent = 100 - 10 (n - 1), where n is the specified positive maneuvering load factor, but this value may not be more than 80 percent.

c. For airplanes that are not conventional (such as airplanes with horizontal surfaces other than main wing having appreciable dihedral or supported by the vertical tail surfaces), the surfaces and supporting structures must be designed for combined vertical and horizontal surface loads resulting from each prescribed flight condition taken separately.

a. A sudden movement of the pitching control at the speed V_A to the maximum aft movement and the maximum forward movement as limited by the control stops or pilot effort, whichever is critical.

b. A sudden aft movement of the pitching control at speeds above V_A followed by a forward movement of the pitching control resulting in the following combinations of normal and angular acceleration:

CONDITION	NORMAL ACCELERATION (n)	ANGULAR ACCELERATION (radian/sec_2)
Nose-up pitching...	1.0	$+39n_m + V^*(n_m - 1.5)$
Nose-down pitching...	n_m	$-39n_m + V^*(n_m - 1.5)$

where:

n_m = positive limit maneuvering load factor used in the design of the airplane, and
V = initial speed in knots.

The conditions in this paragraph involve loads corresponding to the loads that may occur in a checked maneuver (a maneuver in which the pitching control is suddenly displaced in one direction and then suddenly moved in the opposite direction). The deflections and timing of the checked maneuver must avoid exceeding the limit maneuvering load factor. The total horizontal surface load for both nose-up and nose-down pitching conditions is the sum of the balancing loads at V and the specified value of the normal load factor n plus the maneuvering load increment due to the specified value of the angular acceleration.

12.2.8 FAR 23.425 Gust Loads (Horizontal Tail).

a. Each horizontal surface, other than a main wing, must be designed for loads resulting from

(1) gust velocities specified in FAR 23.333(c) with flaps retracted and

(2) positive and negative gusts of 25 fps nominal intensity at V_F corresponding to the flight conditions specified in 23.345(a)(2).

b. [Reserved]

c. When determining the total load on the horizontal surfaces for the conditions specified in paragraph a. of this section, the initial balancing loads for steady unaccelerated flight at the pertinent design speeds V_F, V_C, and V_D must first be determined. The incremental load resulting from the gusts must be added to the initial balancing load to obtain the total load.

μ_{gt} = $2W/PC_tg\alpha_{vt}S_{vt}(K/1_t)^2$ = lateral mass ratio,
U_{de} = Derived gust velocity (fps),
P = Air density (slugs/cu ft),
W = Airplane weight (lb),
S_{vt} = Area of vertical surface (ft^2),
C_t = Mean geometric chord of vertical surface (ft),
α_{vt} = Lift curve slope of vertical surface (per radian),
K = Radius of gyration in yaw (ft),
1_t = Distance from airplane c.g. to lift center of vertical surface (ft),
g = Acceleration due to gravity (ft/sec^2), and
V = Airplane equivalent speed (knots).

12.2.12 FAR 23.471 General (Ground Loads).

The limit ground loads specified in this subpart are considered to be external loads and inertia forces that act upon an airplane structure. In each specified ground load condition, the external reactions must be places in equilibrium with the linear and angular inertia forces in a rational or conservative manner.

12.3 RUNNING SELECT.

To run SELECT, select the button from the main menu window. The first window will be displayed as shown in figure 12.2.

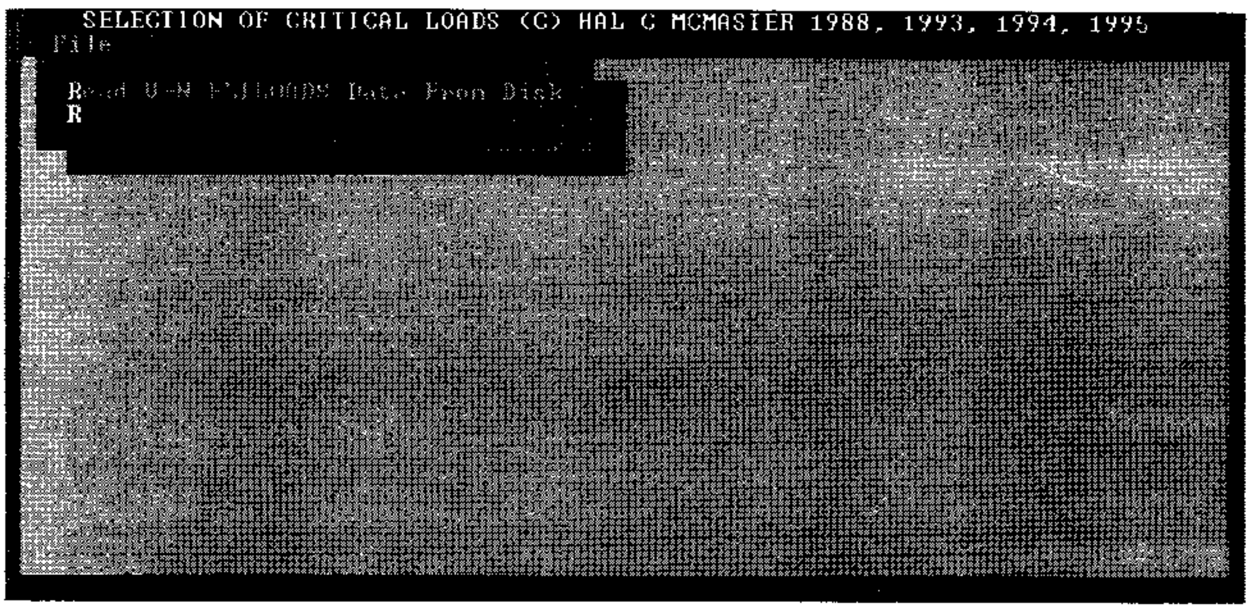

FIGURE 12.2 SELECT MAIN WINDOW

12.2.10 FAR 23.441 Maneuvering Loads (Vertical Surfaces).

a. At speeds up to $V_{A,K}$ the vertical surfaces must be designed to withstand the following conditions. In computing the loads, the yawing velocity may be assumed to be zero:

(1) With the airplane in unaccelerated flight at zero yaw, it is assumed that the rudder control is suddenly displaced to the maximum deflection, as limited by the control stops or by limit pilot forces.

(2) With the rudder deflected as specified in paragraph a.(1) of this section, it is assumed that the airplane yaws to the resulting sideslip angle. In lieu of a rational analysis, an overswing angle equal to 1.3 times the static sideslip angle of paragraph a.(3) of this section may be assumed.

(3) A yaw angle of 15 degrees with the rudder control maintained in the neutral position (except as limited by pilot strength).

b. [Reserved]

c. The yaw angles specified in paragraph a.(3) of this section may be reduced if the yaw angle chosen for a particular speed cannot be exceeded in

(1) steady slip conditions,
(2) uncoordinated rolls from steep banks, or
(3) sudden failure of the critical engine with delayed corrective action.

12.2.11 FAR 23.443 Gust Loads (Vertical Surfaces).

a. Vertical surfaces must be designed to withstand, in unaccelerated flight at speed $V_{C,K}$, lateral gusts of the values prescribed for V_C in FAR 23.333(c).

b. In addition, for commuter category airplanes, the airplane is assumed to encounter derived gusts normal to the plane of symmetry while in unaccelerated flight at V_B, V_C, V_D, and V_F. The derived gusts and airplane speeds corresponding to these conditions, as determined by FARs 23.341 and 23.345, must be investigated. The shape of the gust must be as specified in FAR 23.333(c)(2)(i).

c. In the absence of a more rational analysis, the gust load must be computed as follows:

$$L_{vt} = \frac{K_{gt} U_{de} V a_{vt} S_{vt}}{498}$$

where:

L_{vt} = Vertical surface load (lb),
K_{gt} = $0.88\,\mu_{gt}/5.3 + \mu_{gt}$ = gust alleviation factor,

The View option opens a Notepad program, allowing you to review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

12.3.3 Input Windows.

After a selection is made, one of the input windows is displayed. These input windows are shown in figures 12.4 through 12.7. Each input window includes four menu options: File, Select, View, and Color.

The File menu is used to store and retrieve data from the program. *Save V-n FLTLOADS Data and Inputs* allows the V-n data and input data to be saved to a file. *Print V-n FLTLOADS Data* allows you to print the V-n data to a file or printer. *Save Critical Component Loads* allows you to perform the calculations and save the critical loads to a file. *Print Critical Component Loads* allows you to perform the calculations and send the output to a printer or file. The component is either wing, fuselage, horizontal tail, or vertical tail, depending on which loads you are selecting. *Return to Main Menu* exits from SELECT and returns to the FAR23 Loads Main Menu.

The Select option allows you to select the type of analysis that you will do. After you select an analysis type and enter the data, you must use the File menu to perform the calculations. You can do the analysis for a component only while you are in the appropriate window.

The View option opens a Notepad program, allowing you to review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

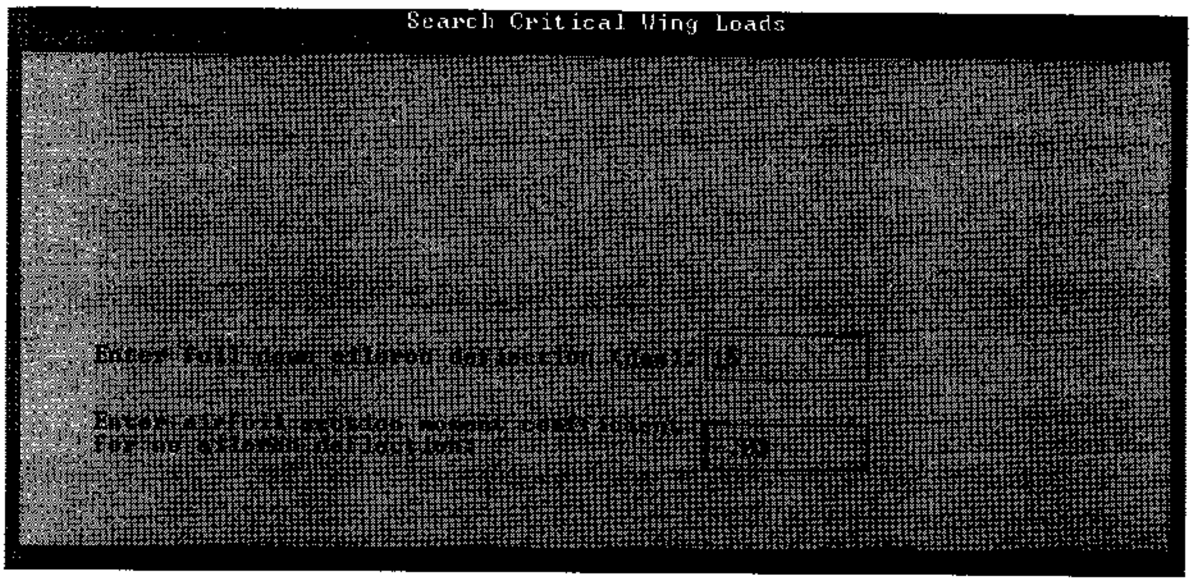

FIGURE 12.4 SELECT "SEARCH CRITICAL WING LOADS" WINDOW

12.3.1 Main Window.

The first window is used to specify the file containing the V-n data. You must open a data file before you can do any analysis. This window includes three menu options: File, View, and Color.

The File menu contains two options: *Read V-n FLTLOAD Data From Disk* and *Return to Main Menu*. The V-n data file comes from FLTLOADS (section 11). If you try to open a file that is not the correct format, you will get an error message.

The View option opens a Notepad program, allowing you to review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

12.3.2 Secondary Window.

After a V-n data file is opened, the window options change to include Select as well as View and Color as shown in figure 12.3.

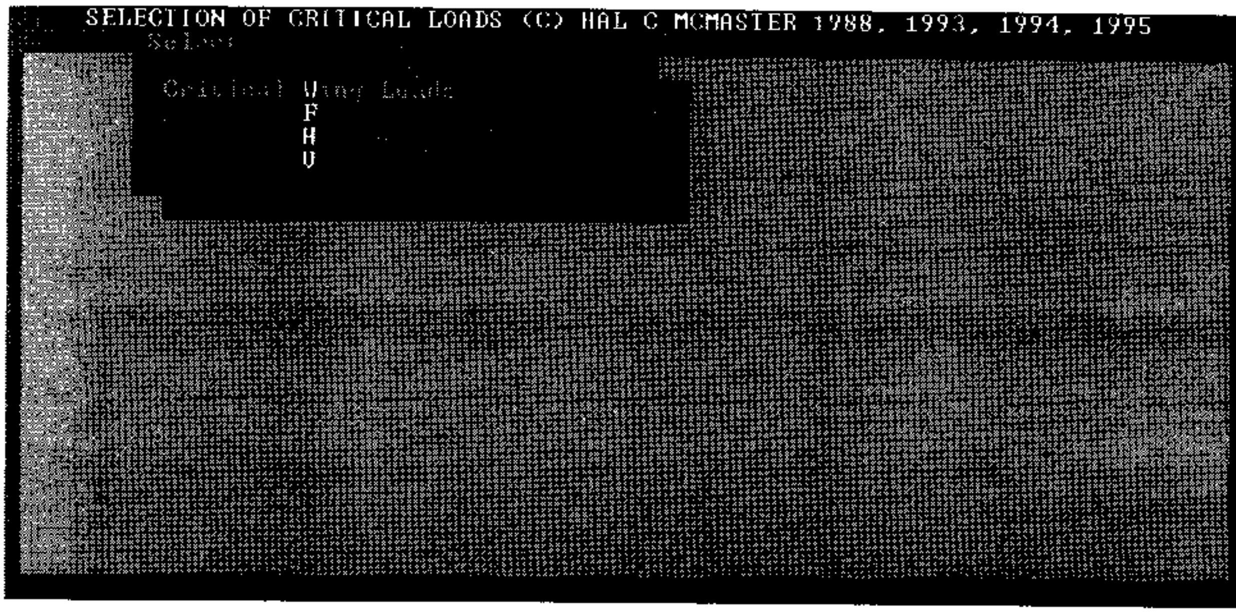

FIGURE 12.3 SELECT SECONDARY WINDOW

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Save V-n FLTLOADS Data and Inputs* will allow the input data to be saved to a file. *Print V-n FLTLOADS Data* allows you to print the V-n data to a file or printer. *Return to Main Menu* exits from SELECT and returns to the FAR23 Loads Main Menu.

The Select option allows you to select the type of analysis that you will do. The options are *Critical Wing Loads*, *Critical Fuselage Loads*, *Critical Horizontal Tail Loads*, and *Critical Vertical Tail Loads.*

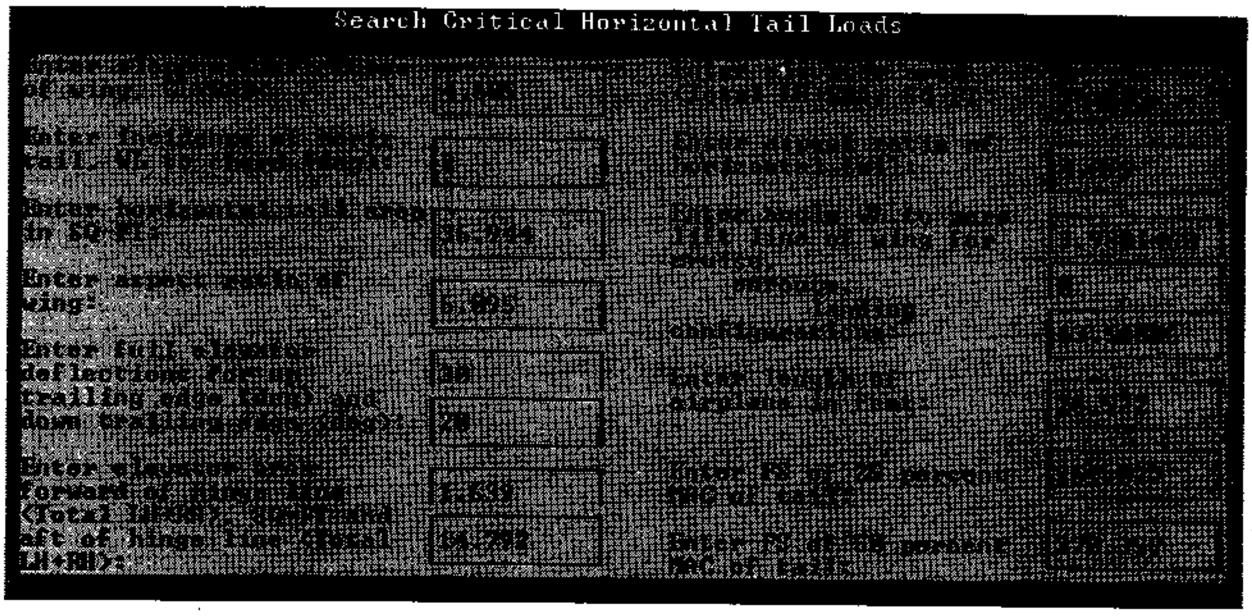

FIGURE 12.6 SELECT "SEARCH CRITICAL HORIZONTAL TAIL LOADS" WINDOW

For the vertical tail critical loads, the data required for analysis is shown in figure 12.7a. This includes

- total area of the vertical tail (ft^2),
- full rudder deflection (degrees),
- area of the rudder forward and aft of hinge line and total (ft^2),
- aspect ratio of vertical tail,
- MAC of vertical tail (ft),
- 25% MAC of vertical tail (ft),
- length of airplane, and
- wing span (ft).

You are also asked if you will use the default moment of inertia to calculate the gust on the vertical tail. If you answer Y, there are no more questions. If you answer N, then you are asked to enter the moment of inertia for the four c.g. locations as shown in figure 12.7b.

The default answer for this question is Y. When you change this to N, the additional questions do not appear until you change to a different window; then come back to the vertical tail loads window.

For each analysis type, there is one input window. The input window for the critical wing loads is shown in figure 12.4. For the critical wing loads, you will be asked to enter the full-down aileron deflection and the airfoil section moment coefficient for no aileron deflection.

Figure 12.5 shows the input window for the critical fuselage loads. You will be asked where the engine is mounted and the wing weight. If you leave the wing weight blank, then a weight of 9% of the gross weight will be used.

Before selecting the fuselage loads, you must calculate the horizontal tail loads. You will get a message if you try to select the fuselage loads before calculating the horizontal tail loads.

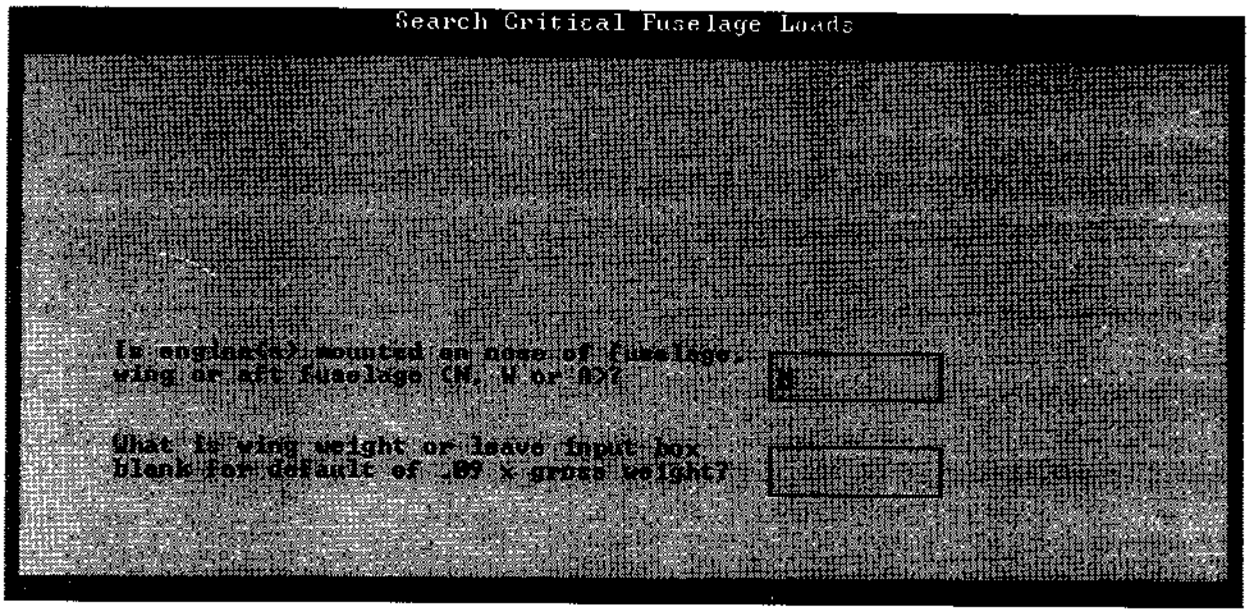

FIGURE 12.5 SELECT "SEARCH CRITICAL FUSELAGE LOADS" WINDOW

The data that needs to be entered to calculate the critical horizontal tail loads are shown in figure 12.6. The following data is required:

- slope of the lift curve of the wing,
- incidence of the horizontal tail (degrees),
- horizontal tail area (ft^2),
- elevator area forward and aft of hinge line and total area of elevator (ft^2),
- aspect ratio of horizontal tail,
- full elevator deflection for up and down trailing edge (degrees),
- fuselage station of 25% and 50% MAC of tail,
- angle of WL to zero lift line for cruise, enroute, and landing configurations,
- aspect ratio of the wing, and
- length of airplane (ft).

After entering the data for a component, you must save the critical loads for that component before moving to the next component. You can only save the critical loads for a component while you are in the appropriate window.

When you save data to a file, give each component a unique file name. If a file already exists, it will be overwritten.

12.4 SELECT OUTPUT.

SELECT determines the critical loads for the wing, fuselage, vertical tail, and horizontal tail. A separate output file is created for each component. The output file lists each critical condition, with appropriate parameters.

The results from SELECT are used in AIRLOADS or AIRLOAD4 (section 9 or 10), WINGINER (section 15), and TAILDIST (section 20) to calculate the loads.

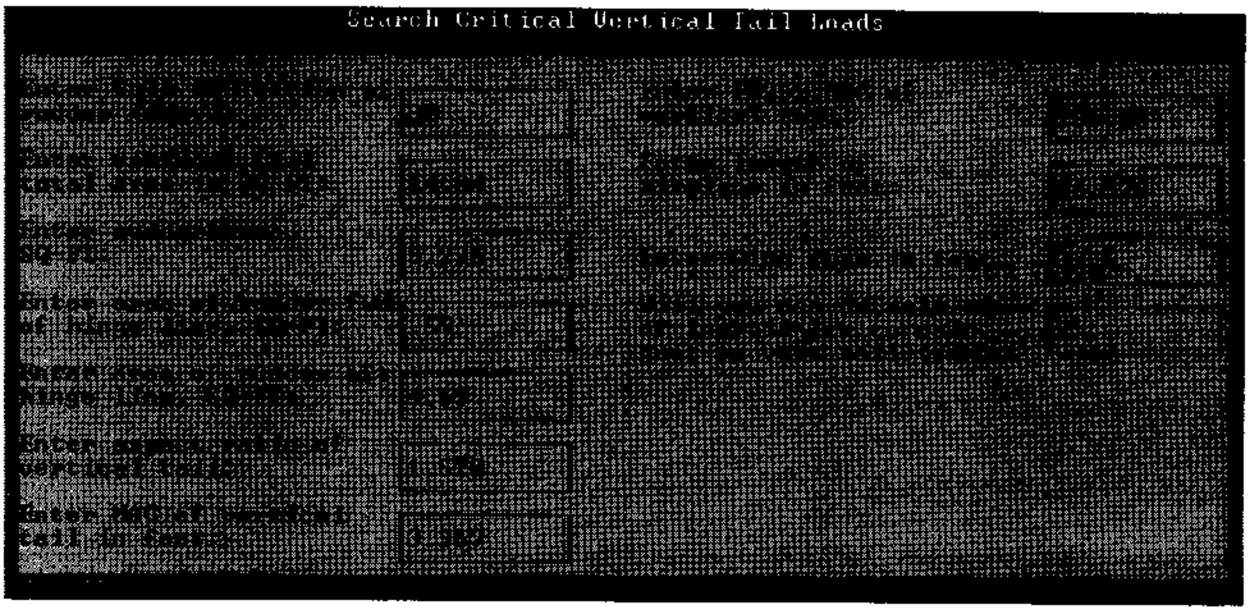

FIGURE 12.7a SELECT "SEARCH CRITICAL VERTICAL TAIL LOADS" WINDOW

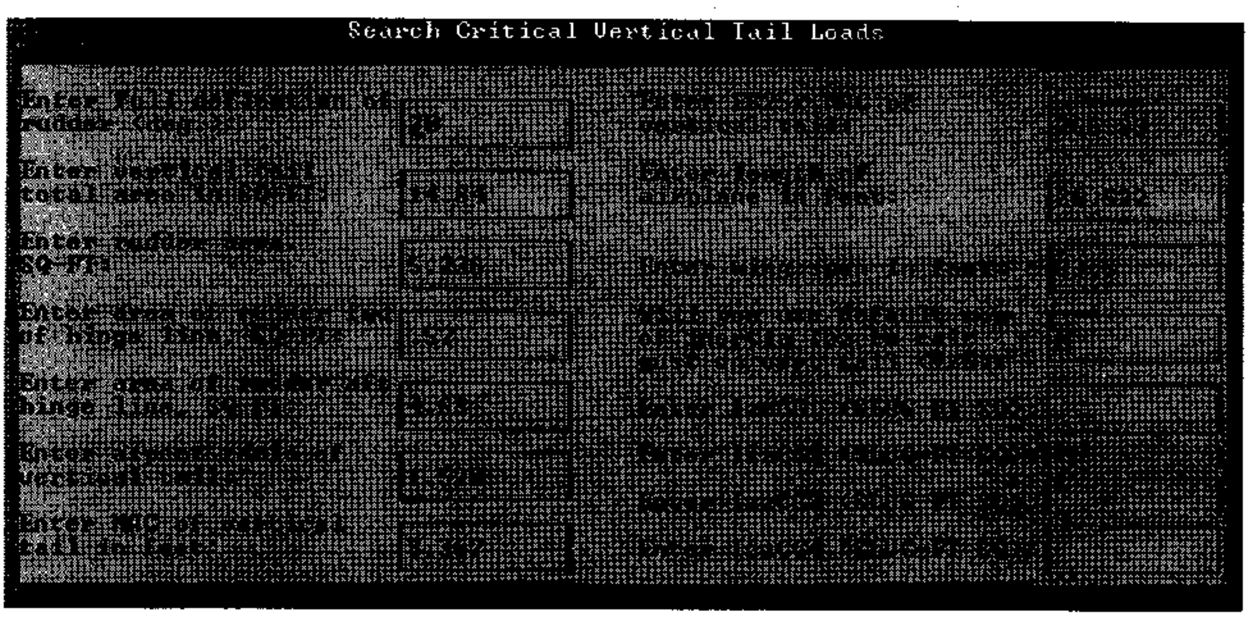

FIGURE 12.7b SELECT "SEARCH CRITICAL VERTICAL TAIL LOADS" WINDOW

12.3.4 Running the Analysis.

For each analysis type, after all inputs are entered in the input window, start the analysis by opening the File menu and selecting *Save Critical Component Loads* or *Print Critical Component Loads Data*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

You must run the analysis for the horizontal tail before you can run the fuselage analysis.

The dynamic pressure q is calculated for sea level:

$$q = \frac{1}{2}\rho_0 V^2$$

where:

ρ_0 = air density at sea level, 2.3769×10^{-3} slugs/ft^3
V = equivalent air speed (ft/sec)

The air speed is entered in knots and then converted to ft/sec.

On the aileron, the pressure distribution is constant from the leading edge of the aileron to the hinge line, then tapers to zero at the trailing edge. The pressure forward of the hinge line is calculated for the largest up and down loads:

$$P = \frac{L}{S_{ail-fwd} + 0.5 S_{ail-aft}}$$

where:

P = pressure
L = load
$S_{ail\text{-}fwd}$ = surface area forward of the hinge line
$S_{ail\text{-}aft}$ = surface area aft of the hinge line

13.2 FAR 23 REGULATIONS.

The FAR requirements for the aileron loads are defined in FAR 23.455 and repeated here for convenience.

13.2.1 FAR 23.455 Ailerons.

a. The ailerons must be designed for the loads to which they are subjected:

(1) in the neutral position during symmetrical flight conditions and

(2) by the following deflections (except as limited by pilot effort) during unsymmetrical flight conditions:

(a) sudden maximum displacement of the aileron control at V_A, suitable allowance may be made for control system deflections,

(b) sufficient deflection at V_C, where V_C is more than V_A, to produce a rate of roll not less than obtained in paragraph a.(2)(a) of this section, and

(c) sufficient deflection at V_D to produce a rate of roll not less than one-third of that obtained in paragraph a.(2)(a) of this section.

13. AILERON LOADS.

13.1 AILERON DESCRIPTION.

The loads on the aileron are calculated in the module AILERON. The deflected positions during unsymmetrical flight conditions produce the critical loads.

To calculate the aileron loads, the required data include:

- the airspeeds V_A, V_C, and V_D,
- area of the aileron forward and aft of the hinge line,
- the maximum up deflection at V_A, and
- the maximum down deflection at V_A.

The maximum deflections that are entered for the aileron are specified to occur at the design maneuvering speed, V_A. The deflections for the design cruise speed, V_C, and design dive speed, V_D, are calculated from the ratios of V_A/V_C and V_A/V_D:

$$\delta_C = \delta_A \frac{V_A}{V_C}$$

$$\delta_D = 0.5 \frac{V_A}{V_D}$$

where:

δ_C = deflection at V_C
δ_D = deflection at V_D
δ_A = maximum deflection at V_A
V_A = design maneuvering speed
V_C = design cruise speed
V_D = design diving speed

The load on the aileron is calculated for the maximum up and down deflections at V_A, V_C, and V_D by the equations:

$$L_{ail} = C_{L-ail}\, q S_{ail}$$

$$C_{L-ail} = 0.04\delta_{ail}$$

where:

L_{ail} = load on the aileron (lb)
$C_{L\text{-}ail}$ = lift coefficient for the aileron
q = dynamic pressure (lb/ft^2)
S_{ail} = surface area of the aileron (ft^2)
δ_{ail} = deflection of aileron (degrees)

Note: The up deflection must be a negative deflection. If you enter a positive value when you try to do the analysis, you will get an error message.

13.3.2 Running the Analysis.

After all input are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

13.4 AILERON OUTPUT.

The output from AILERON includes the up and down aileron deflections at V_A, V_C, and V_D. The critical load for the up and down aileron deflection and the pressure forward of the hinge line for up and down aileron is calculated.

The deflection is given in degrees, the critical load is in pounds, and the pressure is given in lb/in^2.

13.3 RUNNING AILERON.

To run AILERON, select the button from the main menu window. The input window for AILERON is shown in figure 13.1.

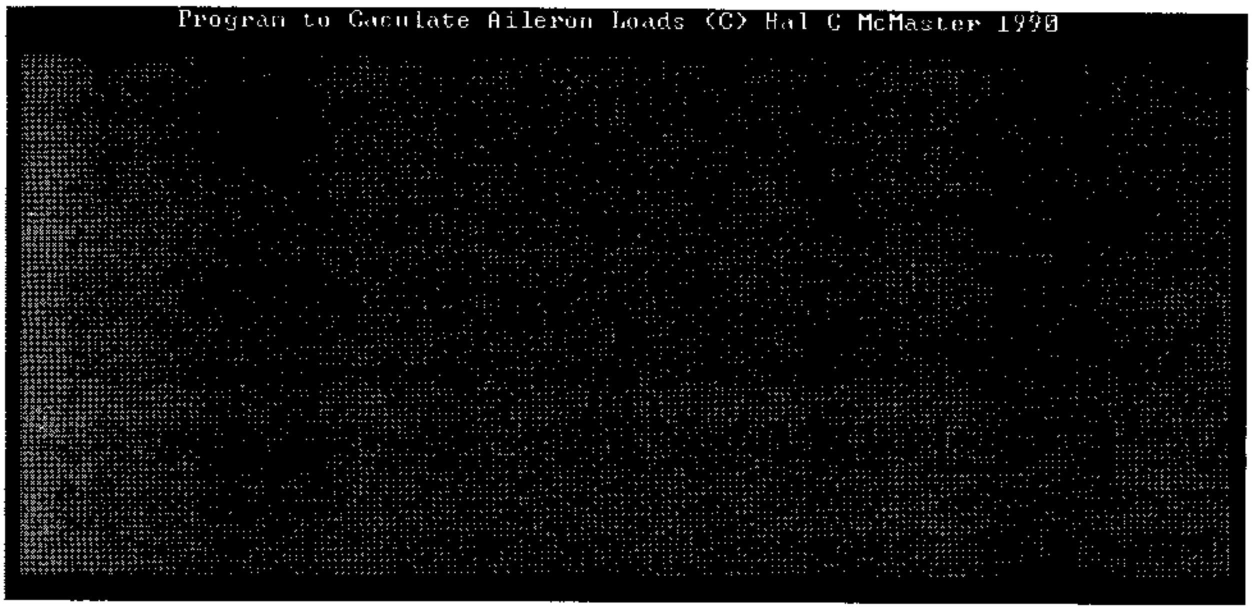

FIGURE 13.1 AILERON INPUT WINDOW

13.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a file or printer. *Return to Main Menu* exits from AILERON and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files, and the Color option allows you to change the color scheme displayed on your window.

The input required for AILERON includes the aileron data and the airspeeds V_A, V_C, and V_D. The airspeeds come from STRSPEED (section 7). Aileron data includes the area of the aileron forward and aft of the hinge line, the maximum up deflection, and the maximum down deflection. The airspeeds are entered in knots, the aileron area is entered as ft^2, and the deflection is in degrees.

b. V_F must be assumed to be not less than 1.4 V_S or 1.8 V_{SF}, whichever is greater, where

(1) V_S is the computed stalling speed with flaps retracted at the design weight, and
(2) V_{SF} is the computed stalling speed with flaps fully extended at the design weight.

However, if an automatic flap load limiting device is used, the airplane may be designed for the critical combinations of airspeed and flap position allowed by that device.

c. In designing the flaps and supporting structures, the following must be accounted for:

(1) A head-on gust having a velocity of 25 fps (EAS).
(2) The slipstream effects specified in FAR 23.457(b).

d. In determining external loads on the airplane as a whole, thrust, slipstream, and pitching acceleration may be assumed to be zero.

e. The requirements of FAR 23.457 and this section may be complied with separately or in combination.

14.2.2 FAR 23.457 Wing Flaps.

a. The wing flaps, their operating mechanisms, and their supporting structures must be designed for critical loads occurring in the flaps-extended flight conditions with the flaps in any position. However, if an automatic flap load-limiting device is used, these components may be designed for the critical combinations of airspeed and flap position allowed by that device.

b. The effects of propeller slipstream, corresponding to takeoff power, must be taken into account at not less than 1.4 V_S, where V_S is the computed stalling speed with flaps fully retracted at the design weight. For the investigation of slipstream effects, the load factor may be assumed to be 1.0.

14.3 RUNNING FLAPLOAD.

To run FLAPLOAD, select the button from the main menu window. The input window for FLAPLOAD is shown in figure 14.1.

14. FLAP LOADS.

14.1 FLAPLOAD DESCRIPTION.

FLAPLOAD calculates the critical flap loads per the requirements of FARs 23.345 and 23.457. The critical flap loads are determined by calculating the lift on the flap due to wing angle of attack plus lift on the flap due to the deflection of the flap.

The chordwise distribution of pressure tapers from the leading edge to the trailing edge. The pressure at the trailing edge is half the pressure at the leading edge. The pressure at the leading edge of the flap is calculated as

$$P_{LE} = \frac{L_{flap}}{0.75 S_{flap}}$$

where:

P_{LE} = pressure at the leading edge
L_{flap} = load on flap
S_{flap} = surface area of flap

The calculation of the propeller slipstream at the flap is based on momentum theory. The area of the slipstream is added to the area of the fuselage or nacelle, and a radius is derived. The butt line of the engine plus or minus the radius determines the inboard and outboard edges of the slipstream.

The critical flap loads in the slipstream are determined by combining the slipstream effects with the critical flap loads. The critical flap loads in the slipstream are increased by the ratio of the dynamic pressure of the slipstream to that out of the slipstream.

The requirement for a 25-fps gust is accounted for by increasing the critical flap load by the ratio of the dynamic pressure of the velocity of the airplane plus 25 fps to the dynamic pressure of the airplane before the gust.

14.2 FAR 23 REGULATIONS.

The FAR requirements for critical flap loads are given in FARs 23.345 and 23.457 and repeated here for convenience.

14.2.1 FAR 23.345 High-Lift Devices.

a. If flaps or similar high-lift devices (used for takeoff, approach, or landing) are installed, the airplane, with the flaps fully deflected at V_F, is assumed to be subjected to symmetrical maneuvers and gusts resulting in limit load factors within the range determined by

   (1) maneuvering to a positive limit load factor of 2.0 and
   (2) positive and negative gust of 25 fps acting normal to the flight path in level flight.

- maximum horsepower of one engine,
- butt line of engine (in),
- frontal area of nacelle (ft^2), and
- propeller diameter (in).

Note: The input window asks for "max gust load factor with flaps," this should say "max gust load factor with flaps extended."

14.3.2 Running the Analysis.

After all inputs are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

14.4 FLAPLOAD OUTPUT.

The output from FLAPLOAD includes the lift coefficients for the wing and flap as well as the flap load for the following conditions: 1 g stall, 2 g stall, 2 g at V_F, and 1.9 g at V_F. Additional output includes the critical flap load and the pressure at the leading edge. The butt line for the inboard and outboard edge of the slipstream are given, as well as the slipstream velocity at the flap. For a horizontal gust of 25 fps, the factor to increase the flap load at V_F and the critical flap load combined with the horizontal gust are given.

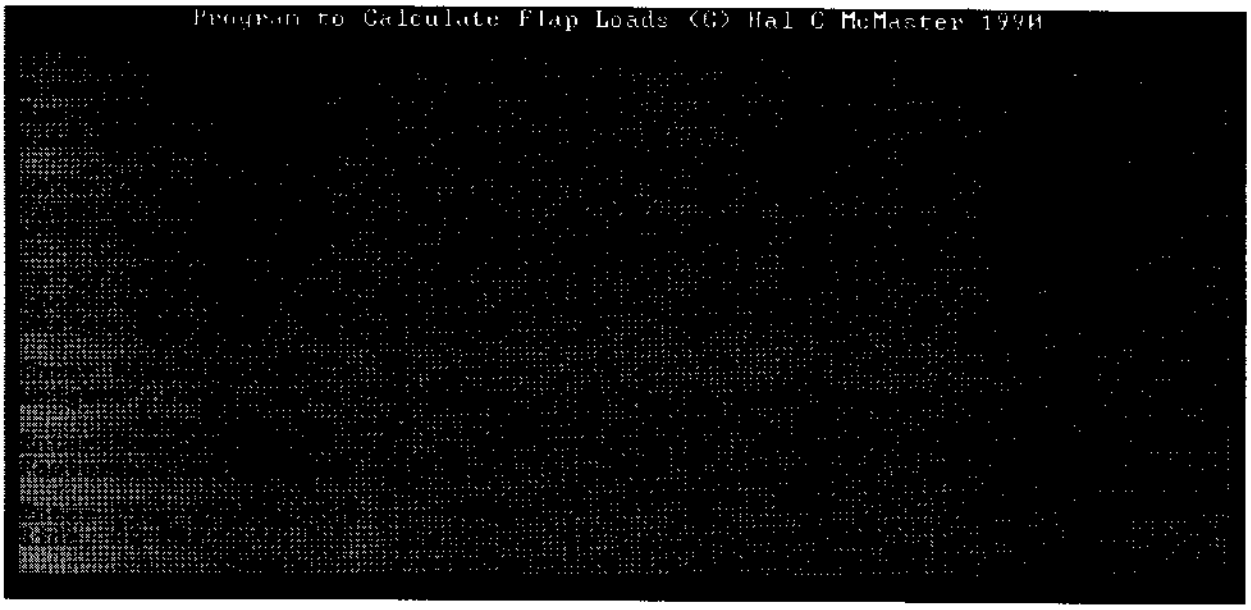

FIGURE 14.1 FLAPLOAD INPUT WINDOW

14.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output file to be saved to a file. *Print Output* allows you to perform the calculations and send the output data to a file or printer. *Return to Main Menu* exits from FLAPLOAD and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input required to calculate the flap loads includes

- stalling speed at maximum takeoff weight with flaps retracted (knots),
- stalling speed at maximum takeoff weight with flaps extended (knots),
- design flap speed (knots) from STRSPEED (section 7),
- maximum takeoff weight (lb),
- gust load factor with flaps extended,
- flap area on one side of the airplane (ft^2),
- total area of the wing (ft^2),
- maximum flap deflection (degrees),
- ratio of flap chord to wing chord,

b. Unless otherwise provided, the air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the airplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution on canard and tandem wing configurations must be validated by flight test measurements unless the methods used for determining those loading conditions are shown to be reliable or conservative on the configuration under consideration.

c. If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

d. Simplified structural design criteria may be used if they result in design loads not less than those prescribed in FARs 23.331 through 23.521. For conventional, single-engine airplanes with design weights of 6,000 pounds or less, the design criteria of Appendix A of this part are an approved equivalent of FARs 23.321 through 23.459. If Appendix A is used, the entire appendix must be substituted for the corresponding sections of this part.

15.3 RUNNING WINGINER.

To run WINGINER, select the button from the main menu window. The first input window will be displayed as shown in figure 15.1.

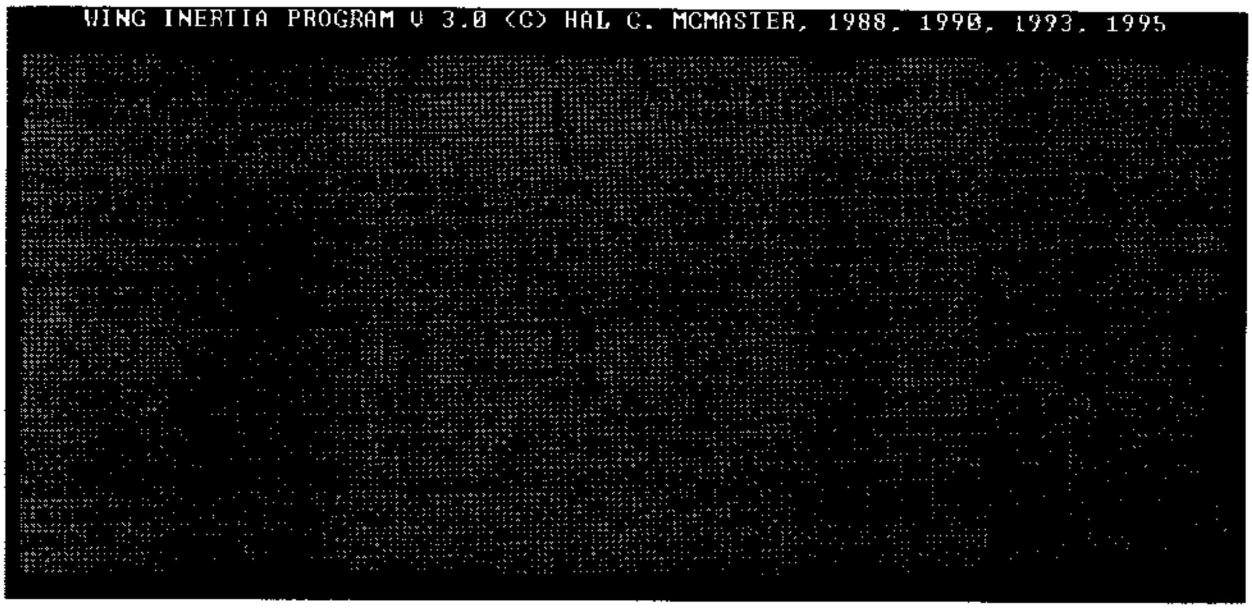

FIGURE 15.1 WINGINER FIRST INPUT WINDOW

15.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes six menu options: File, Notepad, Color, Page1, Page2, and Page3.

15. WING INERTIA.

15.1 WINGINER DESCRIPTION.

WINGINER calculates the spanwise inertia shears and moments in balanced and accelerated flight along the quarter chord of the wing for the critical wing conditions. Concentrated weight such as landing gear, engines, fuel tanks, and external wing stores are accounted for in the calculations.

Using the coordinates of the leading and trailing edges, the wing is divided into incremental chordwise strips. For each strip, the inertia loads, shears, and moments are calculated.

The input required for WINGINER includes wing panel weight, inertia factors obtained for the selected critical wing loads, ratio of densities of the tip area to the root area, wing plan-form geometry, dihedral angle of the wing reference plane and waterline of its intersection with the center plane of symmetry at the quarter chord, weight and coordinates of the concentrated weights, wing station of inboard rib of wing panel, and the load conditions.

For a load condition, the case number, n_x, n_z, and unbalanced moment are required. The case number and n_z come from the V-n data (section 11). You can calculate the value of n_x from

$$n_x = \frac{D_x}{W}$$

where: n_x = load factor for x-direction
D_x = drag load from V-n data (section 11)
W = weight of airplane

If the unbalanced rolling moment is needed, such as for the accelerated roll condition, it can be calculated as described in reference 1.

The inertia loads for the 1 g vertical load, 1 g drag load, and unit rolling moment cases can also be calculated. For the 1 g vertical load, enter n_z as -1 and n_x and unbalanced moment as 0. For the 1 g drag load, n_x is 1 and n_z and unbalanced moment are 0. For the unit rolling moment, unbalanced moment is -100,000 and the load factors n_x and n_z are 0.

15.2 FAR 23 REGULATIONS.

The FAR requirements for loads are given in FAR 23.301 and repeated here for convenience.

15.2.1 FAR 23.301 Loads.

a. Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

If there are less than four concentrated loads, leave the unneeded fields blank or enter 0.

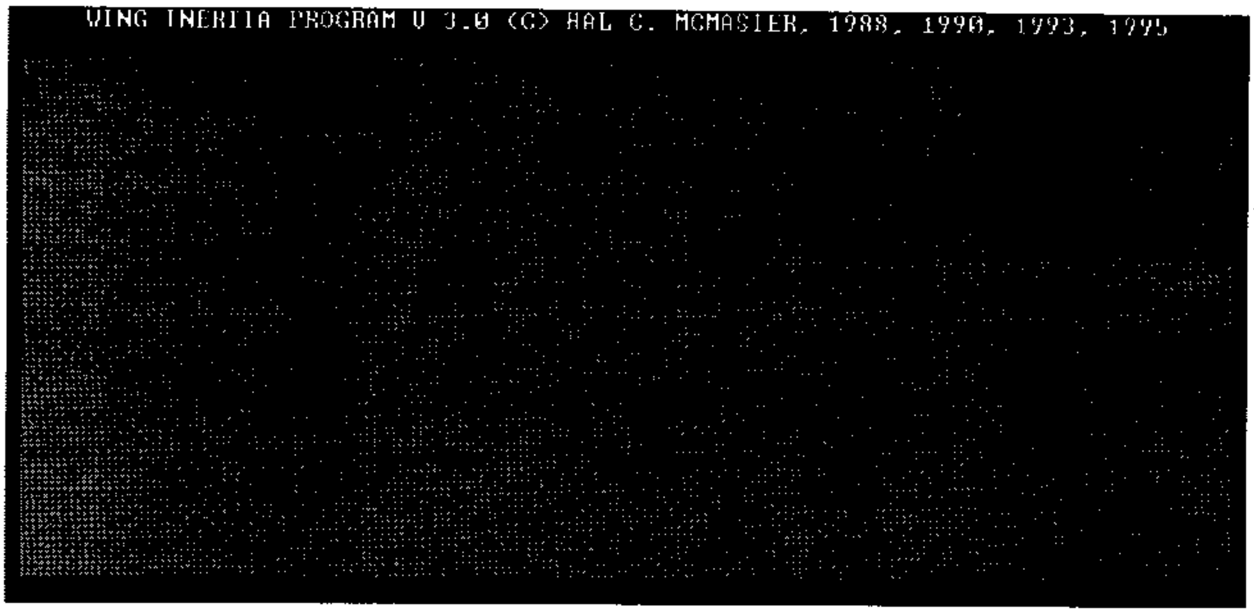

FIGURE 15.3 WINGINER THIRD INPUT WINDOW

The input on the third window includes

- ratio of densities of the tip area to the root area and
- load conditions, including case number, n_z, n_x , and unbalanced moment.

When entering the load cases, use the scroll bar to move to the next point.

The load conditions come from FLTLOADS (section 11). The case number and n_z come directly from the output, but n_x must be calculated as explained above.

The inertia loads for the 1 g vertical load, 1 g drag load, and unit rolling moment cases can also be calculated. For the case number, enter an unused number such as 1001. Each case should have a unique number. For the 1 g vertical load, enter n_z as -1 and n_x and unbalanced moment as 0. For the 1 g drag load, n_x is 1 and n_z and unbalanced moment are 0. For the unit rolling moment, unbalanced moment is -100,000 and the load factors n_x and n_z are 0.

The positive directions are aft and up. Note that the sign for n_z in the output of FLTLOADS and the sign of n_z entered here may not be the same.

15.3.2 Running the Analysis.

After all inputs are entered in the input windows, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a file or printer. *Return to Main Menu* exits from WINGINER and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input required for WINGINER is entered on three input windows as shown in figures 15.1, 15.2, and 15.3. The input on the first window includes

- wing plan-form geometry, entered as coordinates on the leading and trailing edges,
- wing station of inboard rib of the wing panel, and
- number of spanwise increments to divide wing into (between 2 and 100).

When entering the coordinates, use the scroll bar to move to the next point.

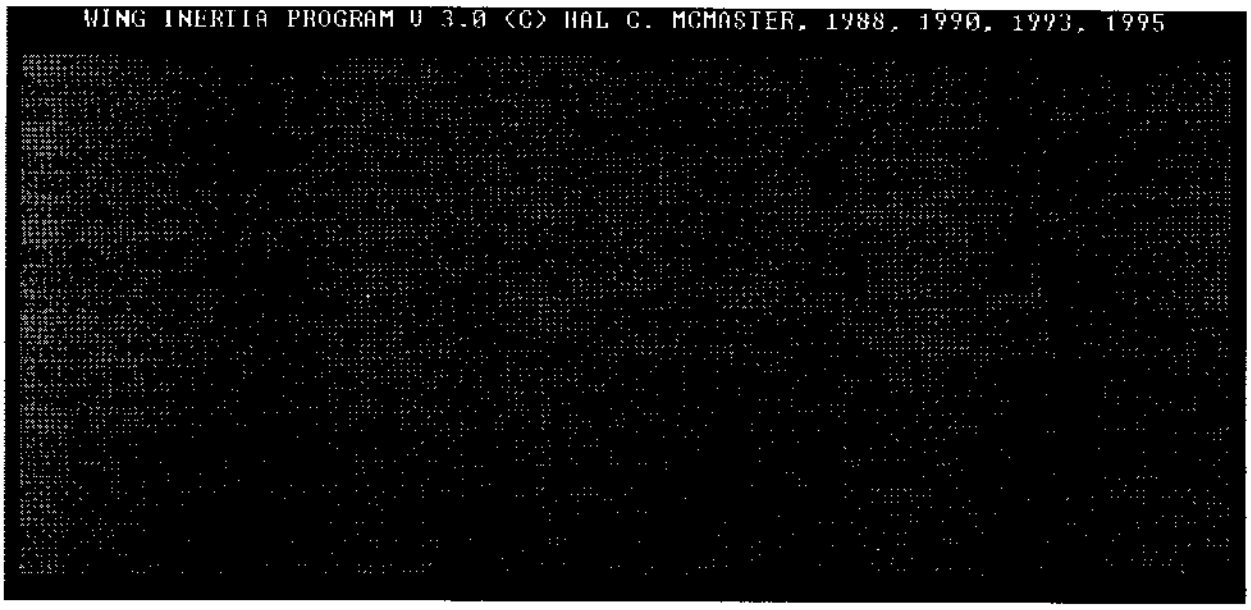

FIGURE 15.2 WINGINER SECOND INPUT WINDOW

The input on the second window includes

- wing panel weight (lb), not including concentrated weight,
- dihedral angle of the wing reference plane and waterline of its intersection with the center plane of symmetry at the quarter chord, and
- weight and coordinates for up to four concentrated weights.

15.4 WINGINER OUTPUT.

For each case, the output includes the load, shear, and torsion for each spanwise increment of the wing. This output is used in NETLOADS (section 16) when determining the total loads.

In the output file, the data is labeled by the variable names. These variable names are defined in table 15.1.

TABLE 15.1 DESCRIPTION OF VARIABLES USED IN THE WINGINER OUTPUT FILE

VARIABLE NAME	DESCRIPTION
Case	Input case number
N_X , N_Z	Input load factor for the x and z direction
THETADOT	Rate of change of the pitch velocity
UNBAL MOM	Input value of unbalanced moment (in-lbs)
X, Y, and Z	Coordinates of the quarter chord for the wing increment (in.)
FX, FZ	Total inertia force in the x and z direction
DMYY	Incremental torsion (in-lbs)
SX, SZ	Total drag force in x and z direction (lbs)
MXX, MYY, MZZ	Bending moment, torsion, and yawing moment (in-lbs)

number of spanwise load points, and then the input window is displayed. The minimum number of load points is 3, and the maximum is 100. *Open* allows you to retrieve a previously created and saved data file (example files include PHAABB36, ACCELROL, and TORBB36). *Return to Main Menu* exits from NETLOADS and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

16.3.1 Input Window.

The input window, shown in figure 16.1, is used to specify the parameters for the analysis. If you specified *New*, the data fields are filled with zeros. If you specified *Open*, the fields will be filled with the data. This window also includes three menu options: File, Notepad, and Color.

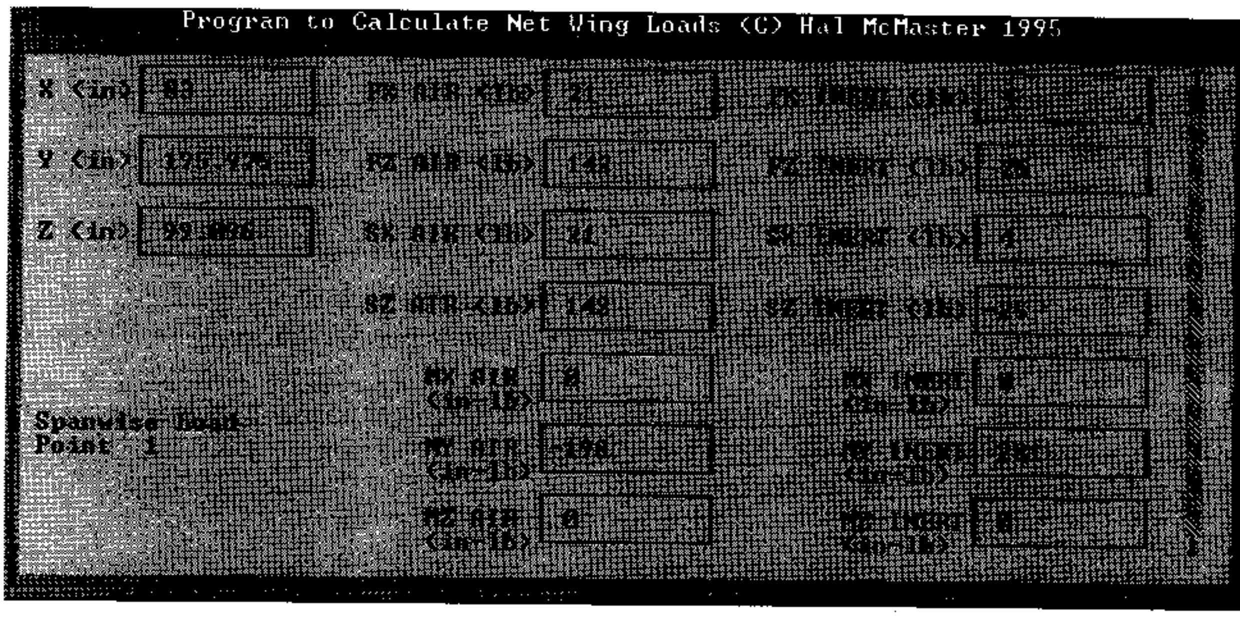

FIGURE 16.1 NETLOADS INPUT WINDOW

After a file is open, the File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a file or printer. *Return to Main Menu* exits from NETLOADS and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

16. NET WING LOADS.

16.1 NETLOADS DESCRIPTION.

The module NETLOADS calculates the spanwise net wing shears and moments along the quarter chord of the wing. The air loads and inertia loads are algebraically added to determine the net loads.

The input data required for the calculations are the air loads and inertia loads for the selected critical loads for the wing. The air loads come from AIRLOADS or AIRLOAD4 (section 9 or 10) and the inertia loads come from WINGINER (section 15).

16.2 FAR 23 REGULATIONS.

The FAR requirements for loads are given in FAR 23.301 and repeated here for convenience.

16.2.1 FAR 23.301 Loads.

a. Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

b. Unless otherwise provided, the air, ground, and water loads must be placed in equilibrium with inertia forces considering each item of mass in the airplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. Methods used to determine load intensities and distribution on canard and tandem wing configurations must be validated by flight test measurement unless the methods used for determining those loading conditions are shown to be reliable or conservative on the configuration under consideration.

c. If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

d. Simplified structural design criteria may be used if they result in design loads not less than those prescribed in FARs 23.331 through 23.521. For conventional, single-engine airplanes with design weights of 6,000 pounds or less, the design criteria of Appendix A of this part are an approved equivalent of FARs 23.321 through 23.459. If Appendix A is used, the entire appendix must be substituted for the corresponding sections of this part.

16.3 RUNNING NETLOADS.

To run NETLOADS, select the button from the main menu window. The first window is displayed when the module starts, and it includes three options: File, Notepad, and Color.

When NETLOADS first starts, the File menu has three options: New, Open, and Return to Main Menu. *New* generates a new input file and window. You are asked to name the file and the

To plot the data with the FAR23 Plot program, the output file from NETLOADS must be saved with a filename with the extension *.NET*.

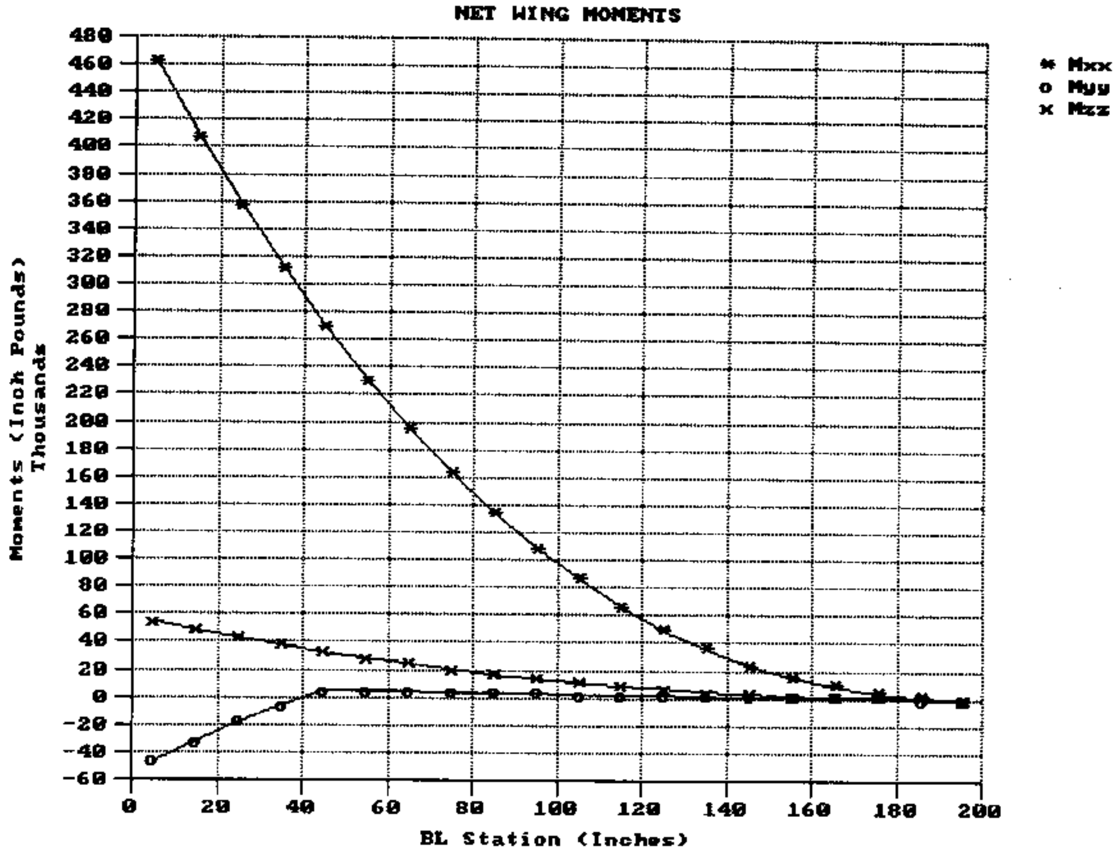

FIGURE 16.2 EXAMPLE OF NET LOADS PLOT

The input required for NETLOADS is

- position of the point (x, y, z coordinates),
- air load information (x, z forces; x, z shears; x, y, z moments), and
- inertia load information (x, z forces; x, z shears; x, y, z moments).

This input data comes from the results of AIRLOADS or AIRLOAD4 and WINGINER (sections 9 or 10, and 15, respectively).

After entering the data for the first point, use the bar on the right side of the window to move to the next point. Continue to enter data until all the points are entered.

If you opened an existing data file, use the scroll bar to review the data and make changes if necessary.

16.3.2 Running the Analysis.

After the inputs are entered for all the points, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

When you run the analysis, you will be asked to enter an identification for the net loads condition. This identification is written to the output file.

16.4 NETLOADS OUTPUT.

The output includes the spanwise net wing loads, shears, and moments along the quarter chord of the wing. In the output file, the data is labeled by the variable names. These variable names are defined in table 16.1. The positive direction is up and aft.

TABLE 16.1 DESCRIPTION OF VARIABLES USED IN THE NETLOADS OUTPUT FILE

VARIABLE NAME	DESCRIPTION
X, Y, Z	Coordinates of the quarter chord
FX, FZ	Normal force in the x and z directions (lb)
SX, SZ	Drag and shear loads (lb)
MX, MY, MZ	Moments (in-lb)

16.5 GRAPHICS.

The separate graphics program FAR23 Plot can be used to draw the net loads graph. An example of this graph is show in figure 16.2. The FAR23 Plot program is described in the appendix of reference 1.

c. The limit engine torque to be considered under paragraph a. of this section must be obtained by multiplying the mean torque by a factor of

(1) 1.25 for turbopropeller installations;
(2) 1.33 for engines with five or more cylinders; and
(3) two, three, or four for engines with four, three, or two cylinders, respectively.

17.2.2 FAR 23.363 Side Load on Engine Mount.

a. Each engine mount and its supporting structure must be designed for a limit load factor in a lateral direction, for the side load on the engine mount, of not less than

(1) 1.33 or
(2) one-third of the limit load factor for flight condition A.

b. The side load prescribed in paragraph a. of this section may be assumed to be independent of other flight conditions.

17.2.3 FAR 23.371 Gyroscopic and Aerodynamic Loads.

For turbine-powered airplanes, each engine mount and its supporting structure must be designed for the combined gyroscopic and aerodynamic loads that result, with the engines at maximum continuous RPM, under either of the following conditions:

a. the conditions prescribed in FARs 23.351 and 23.423 or
b. all possible combinations of the following:

(1) a yaw velocity of 2.5 radians per second,
(2) a pitch velocity of 1 radian per second,
(3) a normal load factor of 2.5, and
(4) maximum continuous thrust.

17.3 RUNNING ENGLOADS.

To run ENGLOADS, select the button from the main menu window. The first input window will be displayed as shown in figure 17.1.

17.3.1 Input Window.

The input window is displayed when ENGLOADS starts and is used to specify the parameters for the analysis. This window includes five menu options: File, Notepad, Color, Page1, and Page2.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform

17. ENGINE MOUNT LOADS.

17.1 ENGLOADS DESCRIPTION.

The module ENGLOADS calculates the loads which must be sustained by the engine mount and its supporting structure. These loads include those resulting from engine torque loads, vertical inertia loads, and side inertia loads. For turbine engines, the torque due to sudden stoppage is also included. For turbine-powered airplanes, the gyroscopic and aerodynamic loads resulting from the combination of yaw velocity, pitching velocity, normal inertia loads, and propeller thrust must be considered.

17.2 FAR 23 REGULATIONS.

The FAR requirements for engine mount loads are given in FAR 23.361 for engine torque, FAR 23.363 for side loads, and FAR 23.371 for gyroscopic and aerodynamic loads.

17.2.1 FAR 23.361 Engine Torque.

a. Each engine mount and its supporting structure must be designed for the effects of

(1) a limit engine torque corresponding to takeoff power and propeller speed acting simultaneously with 75 percent of the limit loads from flight condition A of FAR 23.333(d),

(2) a limit engine torque corresponding to maximum continuous power and propeller speed acting simultaneously with the limit loads from flight condition A of FAR 23.333(d), and

(3) for turbopropeller installations, in addition to the conditions specified in paragraphs a.(1) and a.(2) of this section, a limit engine torque corresponding to takeoff power and propeller speed multiplied by a factor accounting for propeller control system malfunction, including quick feathering, acting simultaneously with 1 g level flight loads (in the absence of a rational analysis, a factor of 1.6 must be used).

b. For turbine engine installations, the engine mounts and supporting structure must be designed to withstand each of the following:

(1) a limit engine torque load imposed by sudden engine stoppage due to malfunction or structural failure (such as compressor jamming) and

(2) a limit engine torque load imposed by the maximum acceleration of the engine.

For a turboprop engine, the input window is shown in figure 17.2b. The following data are required:

- propeller hub weight (lb),
- coordinates for the propeller center of gravity,
- number of compressor rotors,
- diameter, weight, and maximum RPM for each rotor, and
- the time to stop due to sudden stoppage.

When entering the rotor data, use the scroll bar to move to the next point.

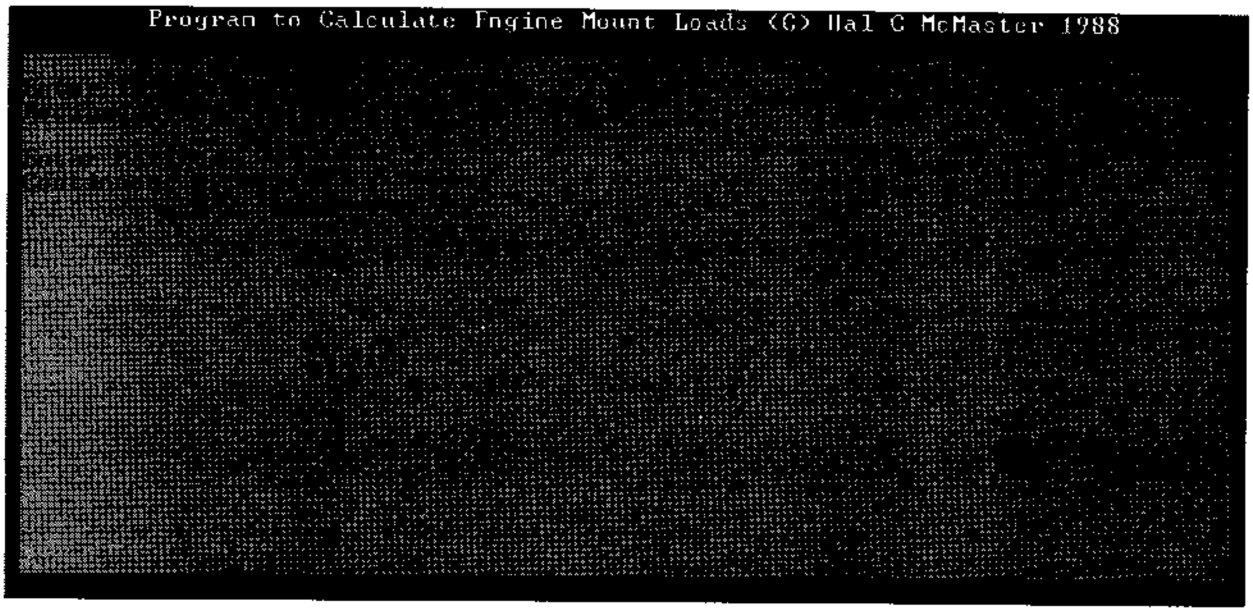

FIGURE 17.2a ENGLOADS SECOND INPUT WINDOW FOR RECIPROCATING ENGINES

17.3.2 Running the Analysis.

After all input are entered in the input windows, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

the calculations and print the output data to a file or printer. *Return to Main Menu* exits from ENGLOADS and returns to the FAR23 Loads Main Menu.

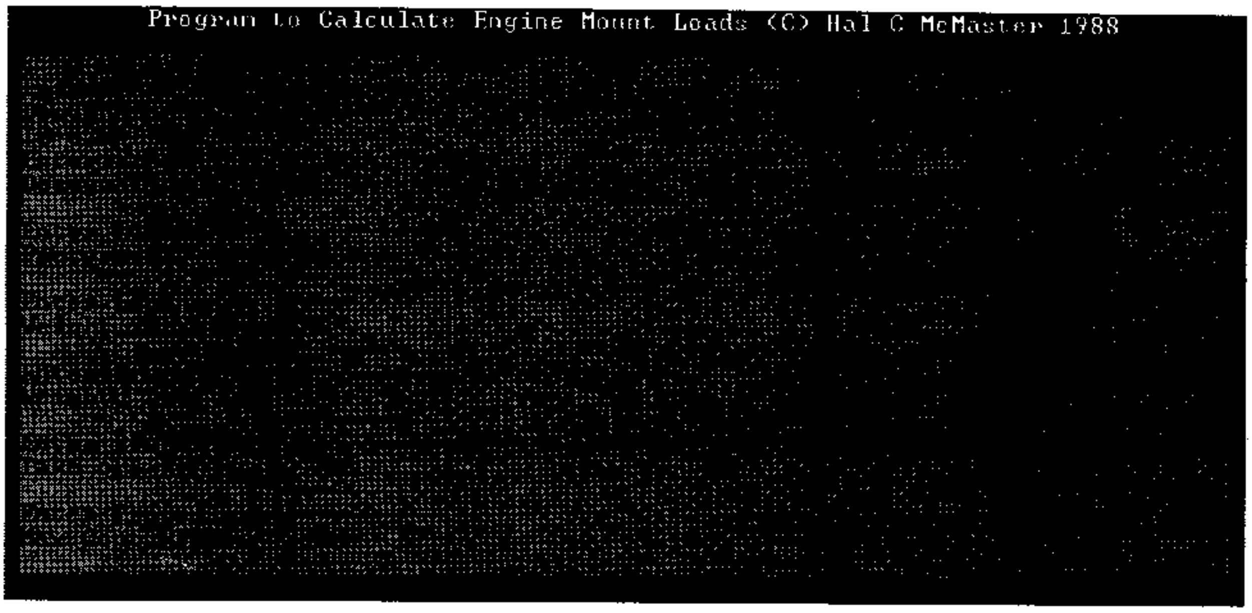

FIGURE 17.1 ENGLOADS FIRST INPUT WINDOW

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input is entered on two input windows. The following data are required in the first input window as shown in figure 17.1:

- the type of engine (reciprocating or turboprop),
- limit load factor (n_z),
- engine weight (lb),
- coordinates for the engine center of gravity,
- propeller weight (lb),
- propeller diameter (inches),
- number of propeller blades,
- takeoff and maximum continuous RPM, and
- titles to describe the engine and propeller manufacturer and designations.

The second input window depends on the type of engine; the two possibilities are shown in figures 17.2a and 17.2b. For a reciprocating engine, the input window is shown in figure 17.2a. The following data are required:

- maximum continuous horsepower,
- takeoff horsepower, and
- number of cylinders.

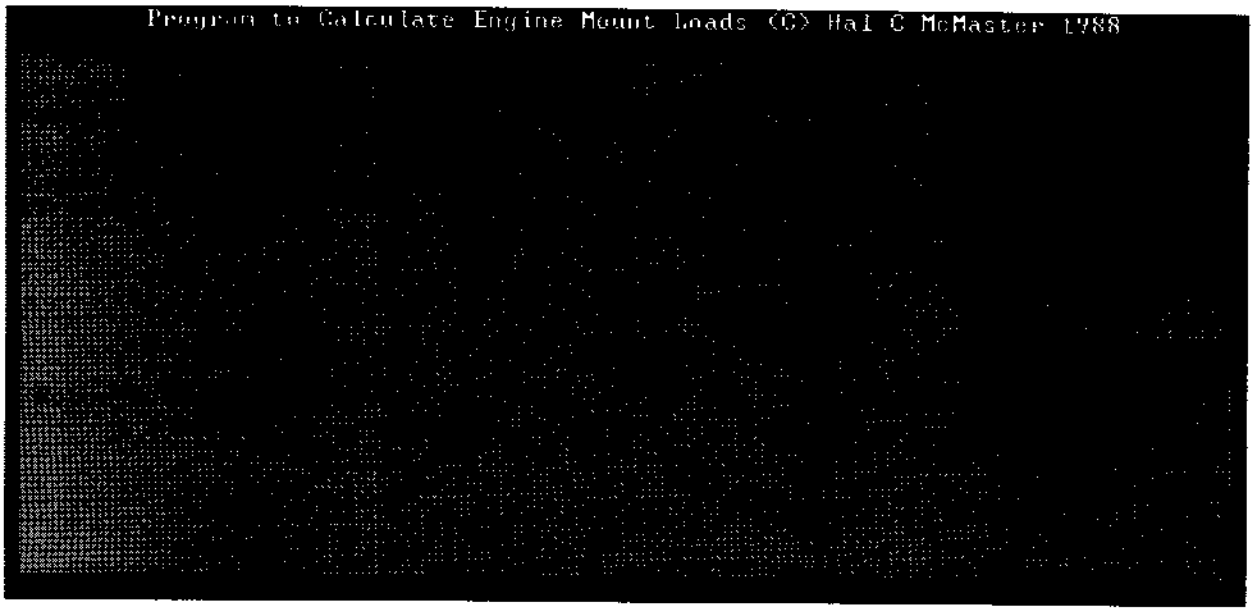

FIGURE 17.2b ENGLOADS SECOND INPUT WINDOW FOR TURBOPROP ENGINES

17.4 ENGLOADS OUTPUT.

For both reciprocating and turboprop engines, the output includes results for the following conditions:

- for limit takeoff torque with 75% limit maneuver vertical load factor,
- a factor times the maximum continuous torque with 100% limit maneuver vertical load factor, and
- side load independent of other flight loads.

The results include the vertical load factor and load, the coordinates where the load acts, and the engine torque. For the side load, the vertical and side load factors are given, as well as the coordinates where the load acts. For each condition, the applicable FAR requirement is specified.

For turboprop engines, additional results are included in the output file. This includes the loads for turboprop propeller malfunction, torque for sudden stoppage due to malfunction, and gyroscopic loads.

(2) compliance is shown with the fuel jettisoning system requirements of FAR 23.1001.

d. The selected limit vertical inertia load factor at the center of gravity of the airplane for the ground load conditions prescribed in this subpart may not be less than that which would be obtained when landing with a descent velocity (V), in feet per second, equal to $4.4(W/S)^{1/4}$, except that this velocity need not be more than 10 feet per second and may not be less than seven feet per second.

e. Wing lift not exceeding two-thirds of the weight of the airplane may be assumed to exist throughout the landing impact and to act through the center of gravity. The ground reaction load factor may be equal to the inertia load factor minus the ratio of the above assumed wing lift to the airplane weight.

f. Energy absorption tests (to determine the limit load factor corresponding to the required limit descent velocities) must be made under FAR 23.723(a) unless specifically exempted by that section.

g. No inertia load factor used for design purposes may be less than 2.67 nor may the limit ground reaction load factor be less than the 2.0 at design maximum weight unless these lower values will not be exceeded in taxiing at speeds up to takeoff speed over terrain as rough as that expected in service.

<u>18.2.3 FAR 23.477 Landing Gear Arrangement</u>.

Sections 23.479 through 23.483, or the conditions in Appendix C of FAR 23, apply to airplanes with conventional arrangements of main and nose gear or main and tail gear.

<u>18.2.4 FAR 23.479 Level Landing Conditions</u>.

a. For a level landing, the airplane is assumed to be in the following attitudes:

(1) For airplanes with tail wheels, a normal level flight attitude.

(2) For airplanes with nose wheels, attitudes in which

(a) the nose and main wheels contact the ground simultaneously and

(b) the main wheels contact the ground and the nose wheel is just clear of the ground.

The attitude used in paragraph a.(2)(a) of this section may be used in the analysis required under paragraph a.(2)(b) of this section.

b. When investigating landing conditions, the drag components simulating the forces required to accelerate the tires and wheels up to the landing speed (spin-up) must be properly combined with the corresponding instantaneous vertical ground reactions, and

18. LANDING LOADS.

18.1 LANDLOAD DESCRIPTION.

The module LANDLOAD calculates the landing loads for a tricycle landing gear with spring or oleo struts. The main and nose gears do not have to be the same type of gear.

The inputs required for calculation of the landing loads include the landing weight, landing gear load factor, assumed lift factor during landing, the station and waterline of the axles for the static position, rolling radius of the tires, distance between main wheels, tail down bump angle, and the weight and c.g. for the structural limits.

18.2 FAR 23 REGULATIONS.

The FAR requirements for landing loads and ground loads are given in FARs 23.471, 23.473, 23.477, 23.479, 23.481, 23.483, 23.485, 23.493, and 23.499 and repeated here for convenience.

18.2.1 FAR 23.471 General.

The limit ground loads specified in FAR 23.471 are the external loads and inertia forces that act upon an airplane structure. In each specified ground load condition, the external reactions must be placed in equilibrium with the linear and angular inertia forces in a rational or conservative manner.

18.2.2 FAR 23.473 Ground Load Conditions and Assumptions.

a. The ground load requirements of FAR 23.473 must be complied with at the design maximum weight, except that FARs 23.479, 23.481, and 23.483 may be complied with at a design landing weight (the highest weight for landing conditions at the maximum descent velocity) allowed under paragraphs b. and c. of this section.

b. The design landing weight may be as low as

   (1) 95 percent of the maximum weight if the minimum fuel capacity is enough for at least one-half hour of operation at maximum continuous power plus a capacity equal to a fuel weight which is the difference between the design maximum weight and the design landing weight or

   (2) the design maximum weight less the weight of 25 percent of the total fuel capacity.

c. The design landing weight of a multiengine airplane may be less than that allowed under paragraph b. of this section if

   (1) the airplane meets the one-engine-inoperative climb requirements of FAR 23.67a. or b.(1) and

c. The limit side inertia factor must be 0.83 with the side ground reaction divided between the main wheels so that

(1) 0.5 (W) is acting inboard on one side and
(2) 0.33 (W) is acting outboard on the other side.

d. The side loads prescribed in paragraph c. of this section are assumed to be applied at the ground contact point and the drag loads may be assumed to be zero.

18.2.8 FAR 23.493 Braked Roll Conditions.

Under braked roll conditions, with the shock absorbers and tires in their static positions, the following apply:

a. The limit vertical load factor must be 1.33.

b. The attitudes and ground contacts must be those described in FAR 23.479 for level landings.

c. A drag reaction equal to the vertical reaction at the wheel multiplied by a coefficient of friction of 0.8 must be applied at the ground contact point of each wheel with brakes, except that the drag reaction need not exceed the maximum value based on limiting brake torque.

18.2.9 FAR 23.499 Supplementary Conditions For Nose Wheels.

In determining the ground loads on nose wheels and affected supporting structures, and assuming that the shock absorbers and tires are in their static positions, the following conditions must be met:

a. For aft loads, the limit force components at the axle must be

(1) a vertical component of 2.25 times the static load on the wheel and
(2) a drag component of 0.8 times the vertical load.

b. For forward loads, the limit force components at the axle must be

(1) a vertical component of 2.25 times the static load on the wheel and
(2) a forward component of 0.4 times the vertical load.

c. For side loads, the limit force components at ground contact must be

(1) a vertical component of 2.25 times the static load on the wheel and
(2) a side component of 0.7 times the vertical load.

the forward-acting horizontal loads resulting from rapid reduction of the spin-up drag loads (spring-back) must be combined with vertical ground reactions at the instant of the peak forward load, assuming wing lift and a tire-sliding coefficient of friction of 0.8. However, the drag loads may not be less than 25 percent of the maximum vertical ground reactions (neglecting wing lift).

c. In the absence of specific tests or a more rational analysis for determining the wheel spin-up and spring-back loads for landing conditions, the method set forth in Appendix D of FAR 23 must be used. If Appendix D of this part is used, the drag components used for design must not be less than those given by Appendix C of FAR 23.

d. For airplanes with tip tanks or large overhung masses (such as turbo-propeller or jet engines) supported by the wing, the tip tanks and the structure supporting the tanks or overhung masses must be designed for the effects of dynamic responses under the level landing conditions of either paragraph a.(1) or a.(2)(b) of this section. In evaluating the effects of dynamic response, an airplane lift equal to the weight of the airplane may be assumed.

18.2.5 FAR 23.481 Tail-Down Landing Conditions.

a. For a tail-down landing, the airplane is assumed to be in the following attitudes:

(1) For airplanes with tail wheels, an attitude in which the main and tail wheels contact the ground simultaneously.

(2) For airplanes with nose wheels, a stalling attitude, or the maximum angle allowing ground clearance by each part of the airplane, whichever is less.

b. For airplanes with either tail or nose wheels, ground reactions are assumed to be vertical with the wheels up to speed before the maximum vertical load is attained.

18.2.6 FAR 23.483 One-Wheel Landing Conditions.

For the one-wheel landing condition, the airplane is assumed to be in the level attitude and to contact the ground on one side of the main landing gear. In this attitude, the ground reactions must be the same as those obtained on that side under FAR 23.479.

18.2.7 FAR 23.485 Side Load Conditions.

a. For the side load condition, the airplane is assumed to be in a level attitude with only the main wheels contacting the ground and with the shock absorbers and tires in their static positions.

b. The limit vertical load factor must be 1.33 with the vertical ground reaction divided equally between the main wheels.

you can view your files. If you run LANDLOAD as a stand-alone program, you can use Notepad to open and print your output file.

The Color option allows you to change the color scheme displayed on your window.

The input is entered on two input windows as shown in figures 18.1 and 18.2. On the first input window, the following data is required:

- maximum landing weight (lb),
- design maximum (or gross) weight (lb),
- landing gear load factor,
- lift factor during landing,
- type of struts (oleo or spring),
- the wing station and waterline of the gear axles for the static deflection and fully extended deflection (inches),
- for oleo struts, the wing station and waterline of the gear axles for the 25% deflection, and
- for spring struts, the wing station and waterline of the gear axles for the 25% deflection (inches).

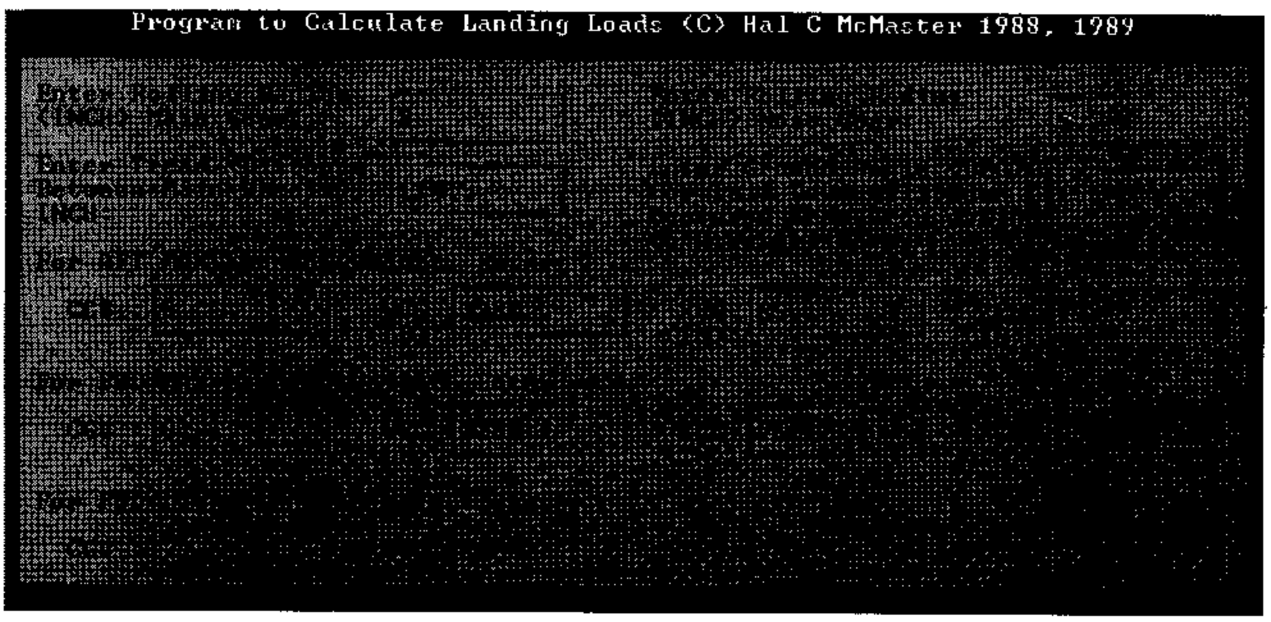

FIGURE 18.2 LANDLOAD SECOND INPUT WINDOW

18.3 RUNNING LANDLOAD.

To run LANDLOAD, select the button from the main menu window. The first input window will be displayed as shown in figure 18.1.

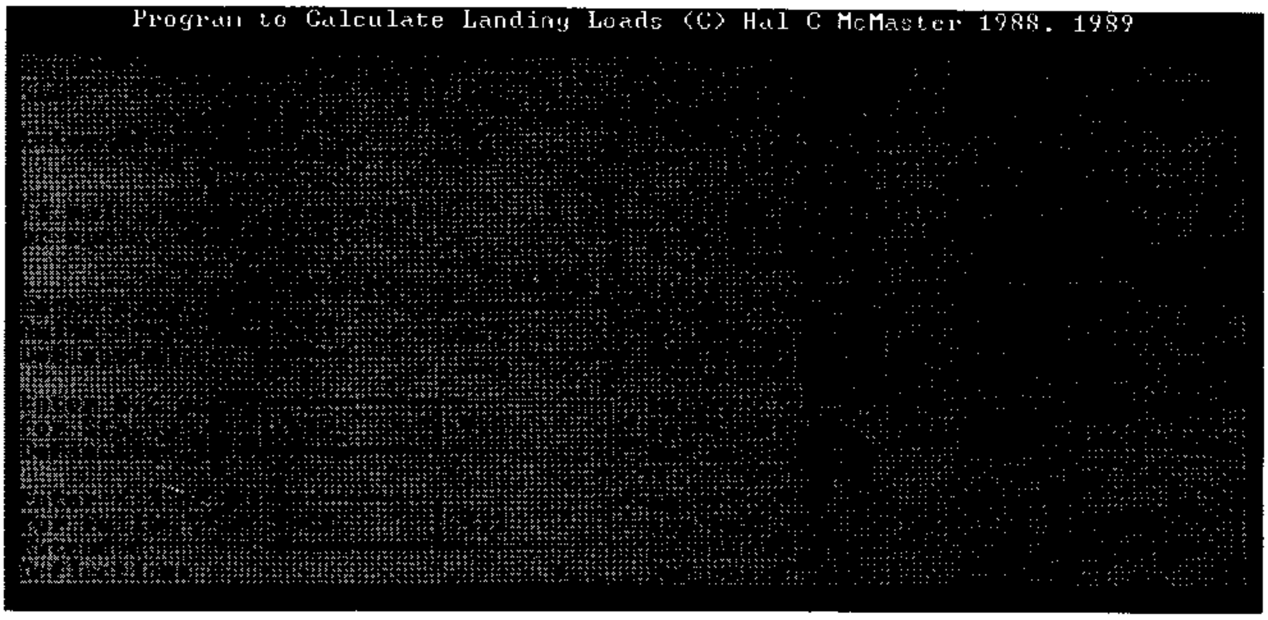

FIGURE 18.1 LANDLOAD FIRST INPUT WINDOW

18.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window includes five menu options: File, Notepad, Color, Page1, and Page2.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a file or printer. *Return to Main Menu* exits from LANDLOAD and returns to the FAR23 Loads Main Menu.

Notes: If you open a data file, you must enter the stroke of the strut. Your value was not saved to the input data file, so this value always appears as 0. If you select *Save Input As*, the value for the stroke of the strut is not saved.

Currently, the *Print Output* option does not work. Therefore, you must use *Save Output As* to save the results to a file.

The Notepad option opens a Notepad program where you can review your input and output files. If you are running LANDLOAD from the FAR23 Load Main Menu, you may have problems opening your output data file. If this happens, you must exit the FAR23 Loads program before

The following input is required on the second window:

- rolling radius of the gear tires (inches),
- distance between main wheels (tread) (inches),
- tail-down bump angle (degrees), and
- weight and c.g. for the structural limits.

There are three structural limits: the aft maximum landing weight, the forward maximum landing weight, and the forward light landing weight. The c.g. data comes from WTONECG (section 4).

Note: If test data is not available, the landing gear load factor can be estimated in LGFACTOR (section 19). If test data becomes available, this load factor should be revised.

18.3.2 Running the Analysis.

After all inputs are entered in the input windows, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. Currently, the second option does not work, so use the option *Save Output As* to save the output to a file, and then print the output from DOS using the Print command.

18.4 LANDLOAD OUTPUT.

In the LANDLOAD output file, the input data is listed. The type of landing gear is not given explicitly, but for oleo struts the x and z coordinates are given for the 25% deflection, while for the spring struts the coordinates are given for the 100% deflection.

The LANDLOAD module calculates the ground reactions and load factors as well as unbalanced moments. The ground reactions and load factors are given relative to the ground line and with respect to the airplane datum.

reaction load factor may be equal to the inertia load factor minus the ratio of the above assumed wing lift to the airplane weight.

f. Energy absorption tests (to determine the limit load factor corresponding to the required limit descent velocities) must be made under FAR 23.723(a) unless specifically exempted by that section.

g. No inertia load factor used for design purposes may be less than 2.67, nor may the limit ground reaction load factor be less than the 2.0 at design maximum weight, unless these lower values will not be exceeded in taxiing at speeds up to takeoff speed over terrain as rough as that expected in service.

19.3 RUNNING LGFACTOR.

To run LGFACTOR, select the button from the main menu window. The input window will be displayed as shown in figure 19.1.

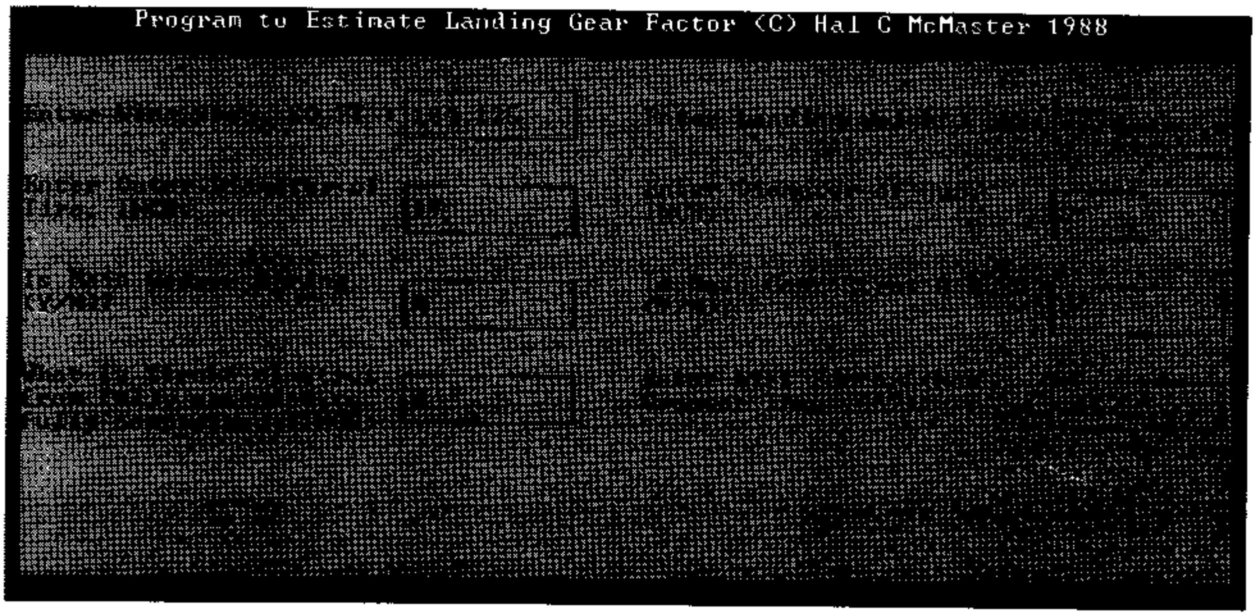

FIGURE 19.1 LGFACTOR INPUT WINDOW

19.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a file or printer. *Return to Main Menu* exits from LGFACTOR and returns to the FAR23 Loads Main Menu.

19. LANDING LOAD FACTOR.

19.1 LGFACTOR DESCRIPTION.

When test data is not available, the landing load factor is estimated in LGFACTOR. This load factor is used in the calculation of landing loads (section 18). After test data is available, the load factor should be revised.

19.2 FAR 23 REGULATIONS.

The requirements for the landing load factor are defined in FAR 23.473 and repeated here for convenience.

19.2.1 FAR 23.473 Ground Load Conditions and Assumptions.

a. The ground load requirements of FAR 23.473 must be complied with at the design maximum weight except that FARs 23.479, 23.481, and 23.483 may be complied with at a design landing weight (the highest weight for landing conditions at the maximum descent velocity) allowed under paragraphs b. and c. of this section.

b. The design landing weight may be as low as

   (1) 95 percent of the maximum weight if the minimum fuel capacity is enough for at least one-half hour of operation at maximum continuous power plus a capacity equal to a fuel weight which is the difference between the design maximum weight and the design landing weight or

   (2) the design maximum weight less the weight of 25 percent of the total fuel capacity.

c. The design landing weight of a multiengine airplane may be less than that allowed under paragraph b. of this section if

   (1) the airplane meets the one-engine-inoperative climb requirements of FAR 23.67a. or b.(1) and

   (2) compliance is shown with the fuel jettisoning system requirements of FAR 23.1001.

d. The selected limit vertical inertia load factor at the center of gravity of the airplane for the ground load conditions prescribed in this subpart may not be less than that which would be obtained when landing with a descent velocity (V), in feet per second, equal to $4.4(W/S)^{1/4}$, except that this velocity need not be more than 10 fps and may not be less than 7 fps.

e. Wing lift not exceeding two-thirds of the weight of the airplane may be assumed to exist throughout the landing impact and to act through the center of gravity. The ground

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

LGFACTOR requires the following input:

- wing area (ft^2),
- landing weight (lb),
- outer diameter of tire (inches),
- diameter of the hub (inches),
- main gear type (either spring or oleo),
- stroke of strut from fully extended to fully retracted (inches), and
- lift factor (must be less than or equal to 0.667).

When entering the type of gear, you must select only one type. Enter Y for either spring or oleo then enter N for the other type.

19.3.2 Running the Analysis.

After all input are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

19.4 LGFACTOR OUTPUT.

The LGFACTOR module produces the following output:

- sink rate,
- airplane load factor, and
- landing gear load factor.

The landing gear load factor is used in LANDLOAD (section 18) when test data is not available.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a printer or file. *Return to TAILDIST Menu* exits and returns to the TAILDIST Main Menu window (figure 20.1).

Currently, the *Print Output* option does not work correctly. Therefore, it is recommended that you use *Save Output As* to save the results to a file, and then use the Notepad option to print the results.

The Notepad option opens a Notepad program where you can review and print your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input required for each of the options is discussed below. The loads data that is used as input comes from the output files of SELECT (section 12). The geometric data that is required input, such as area, was also input for SELECT. However, in SELECT, the area data is entered as ft^2, while in TAILDIST, it must be entered as in^2.

20.2.2 Thirteen Critical Horizontal Tail Loads Distributed on Average Chord.

The input windows for this option are shown in figures 20.2, 20.3, and 20.4. The input required on Page1 includes the area of the horizontal tail, area of the elevator, area of the elevator forward and aft of the hinge line, and the semispan of the tail. The areas are in square inches, and the semispan of the tail is in inches.

Note: The areas are for one side of the horizontal tail. The prompts on the window should all say "Enter area of LH" part.

On Page2 and Page3, the loads due to angle of attack at the 25% MAC and loads due to camber at the 50% MAC are entered for thirteen conditions. These conditions are

- up and down balancing tail load with flaps retracted,
- up and down balancing tail load with flaps extended,
- up and down unchecked maneuver tail load,
- up and down checked maneuver tail load,
- up and down gust tail load with flaps retracted,
- up and down gust tail load with flaps extended, and
- unsymmetrical tail load.

20. DISTRIBUTION OF TAIL LOADS.

20.1 TAILDIST DESCRIPTION.

The TAILDIST module calculates chordwise distributions on the average chord for critical horizontal and vertical tail loads. It also calculates the chordwise distribution for any tail station for any of the critical loads. There are thirteen critical horizontal tail loads and four critical vertical tail loads.

20.2 RUNNING TAILDIST.

To run TAILDIST, select the button from the main menu window. The TAILDIST menu window will be displayed, as shown in figure 20.1. This window also include three other menu options: File, Notepad, and Color.

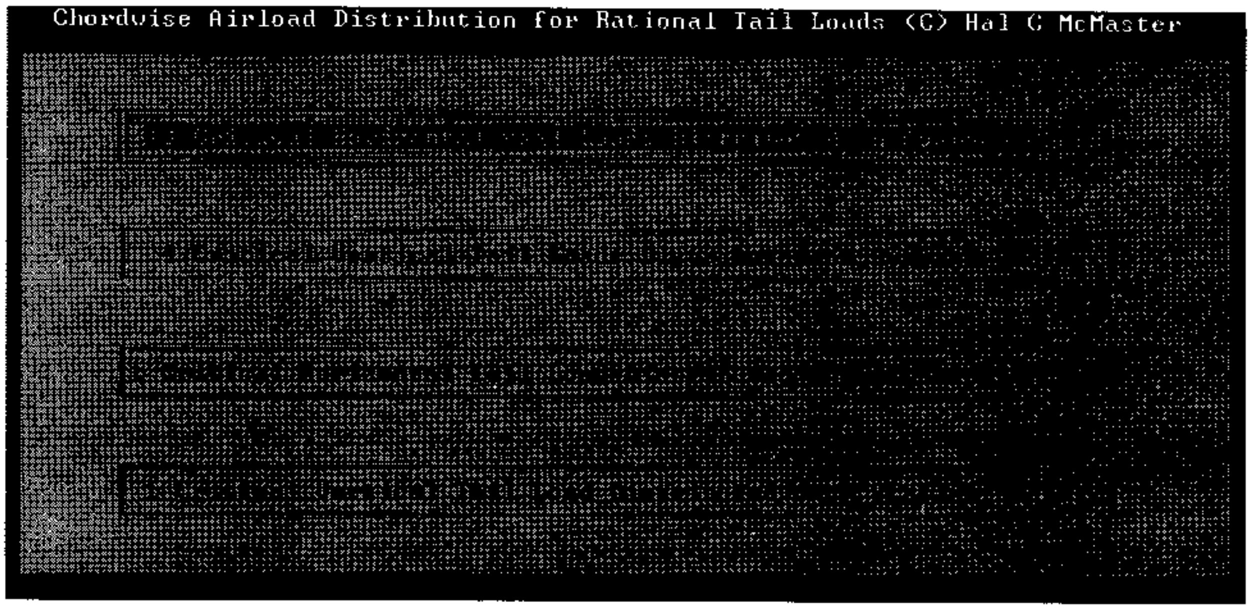

FIGURE 20.1 TAILDIST MENU WINDOW

In the File menu the only option is *Return to Main Menu*, which exits from TAILDIST and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

20.2.1 Input Windows.

After an option is selected from the main menu window, an input window is displayed. This input window is used to specify the parameters for the analysis. Each of the four options in the main menu requires multiple windows, accessed through the Page1, Page2, etc., menu choices. The windows also include three other menu options: File, Notepad, and Color.

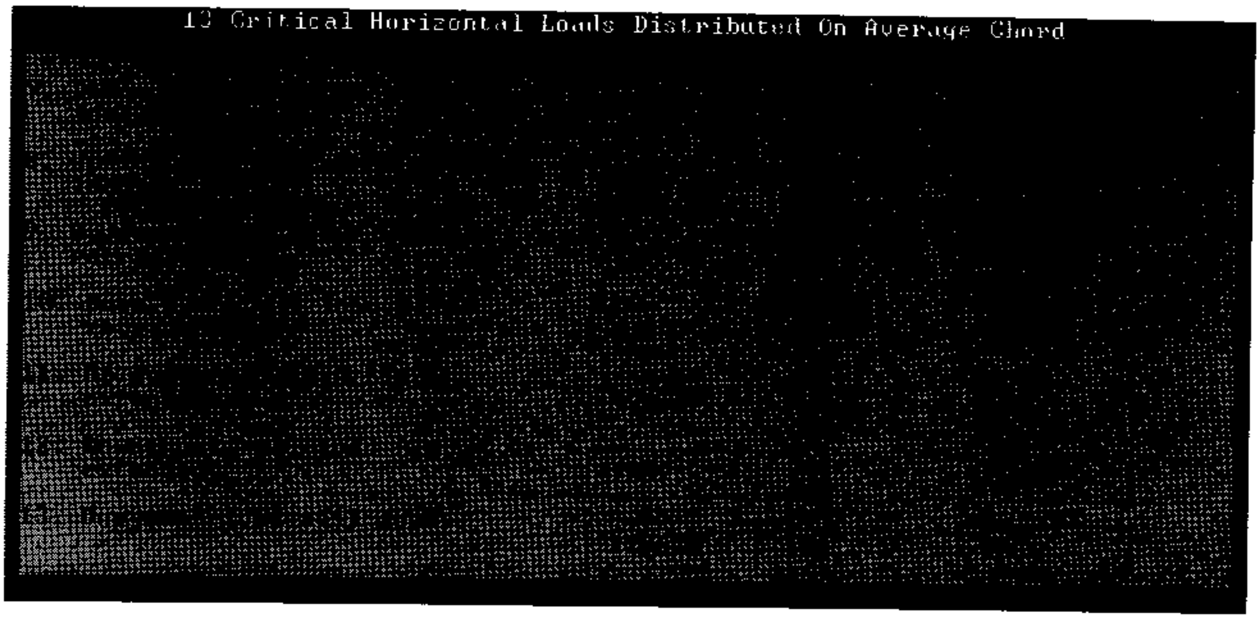

FIGURE 20.4 TAILDIST "13 CRITICAL HORIZONTAL LOADS" THIRD INPUT WINDOW

The loads data comes from the critical horizontal tail loads output file from SELECT. For the gust tail loads, both the incremental and total loads are given in the SELECT file; be sure to enter the total load here. For the unsymmetrical tail load, the SELECT file does not list the loads, but it does tell you which case has the same distribution. You will have to look through the output file to find that case and its load.

When entering the loads, you can use the *Tab* key to accept the data and move to the next cell. However, using the *Tab* key will move you down the columns on the window, thereby entering all of the angle of attack loads first then all the camber loads.

Note: On the first input window (figure 20.2) the third line should read "Enter Area of LH Elevator Fwd of Hinge Line." Also, Page3 does not have headers for the two load columns; these headers are the same as for Page2.

20.2.3 Four Critical Vertical Tail Loads Distributed on Average Chord.

The input windows for this option are shown in figures 20.5 and 20.6. The input required on Page1 includes the area of the vertical tail, area of the rudder, area of the rudder forward and aft of the hinge line, and the span of the tail. The areas are in square inches, and the span of the tail is in inches.

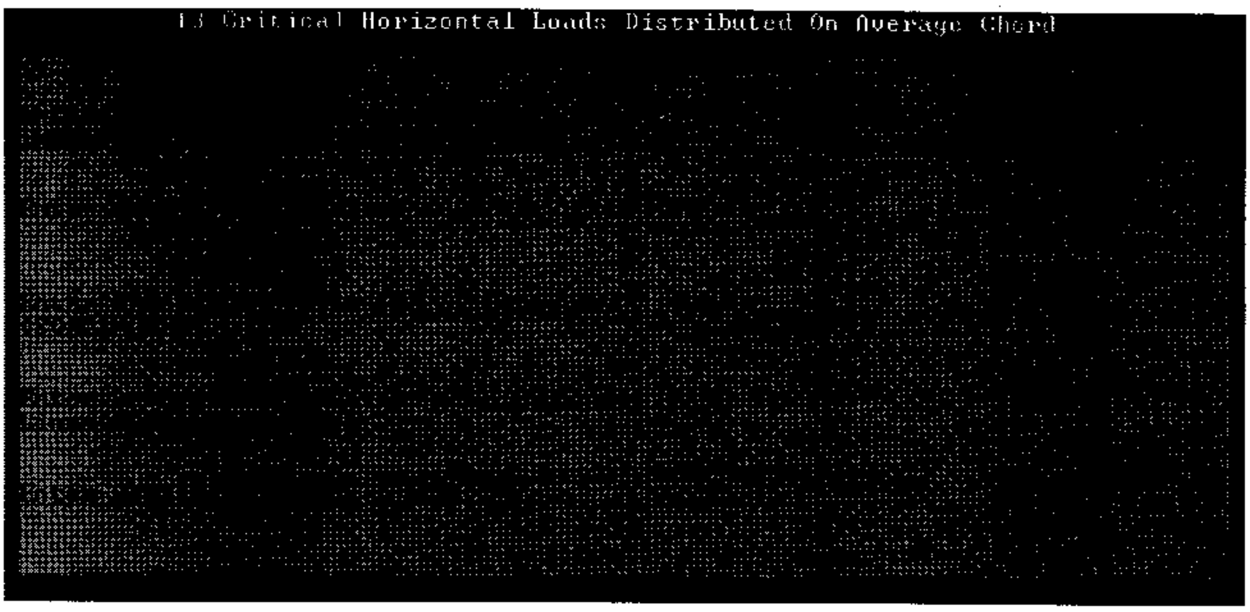

FIGURE 20.2 TAILDIST "13 CRITICAL HORIZONTAL LOADS" FIRST INPUT WINDOW

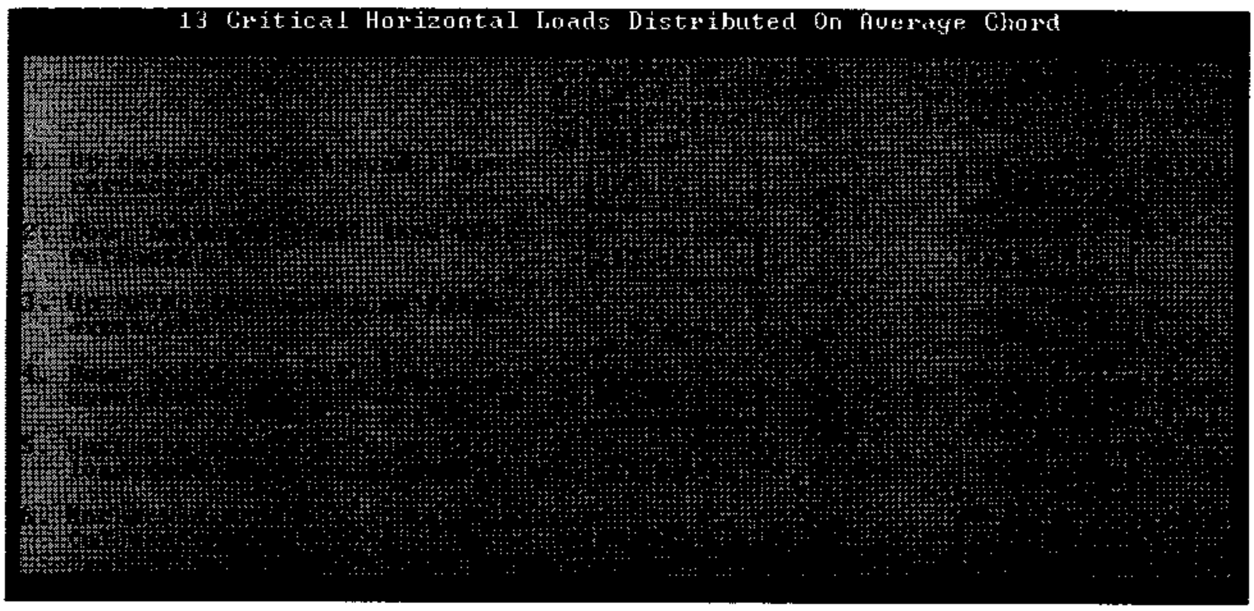

FIGURE 20.3 TAILDIST "13 CRITICAL HORIZONTAL LOADS" SECOND INPUT WINDOW

The loads data comes from the critical vertical tail loads output file from SELECT. Some of the loads may be zero. In this case, do not leave the field blank—be sure to enter a value of 0.0.

When entering the loads, you can use the *Tab* key to accept the data and move to the next cell. However, using the *Tab* key will move you down the columns, thereby entering all of the angle of attack loads first then all the camber loads.

20.2.4 One Critical Horizontal Tail Load Distributed on N Station Chords.

The input windows for this option are shown in figures 20.7 and 20.8. The input required on Page1 includes the name of the load condition, the angle-of-attack load at the 25% MAC, the camber load at the 50% MAC, the area of one side of the horizontal tail, area of the LH elevator aft of the hinge line, and the number of butt line stations for chordwise distribution. The loads are the total load for both right and left sides; however, the area is for only one side. The loads are entered in pounds, the areas are in square inches, and the maximum number of butt line stations is ten.

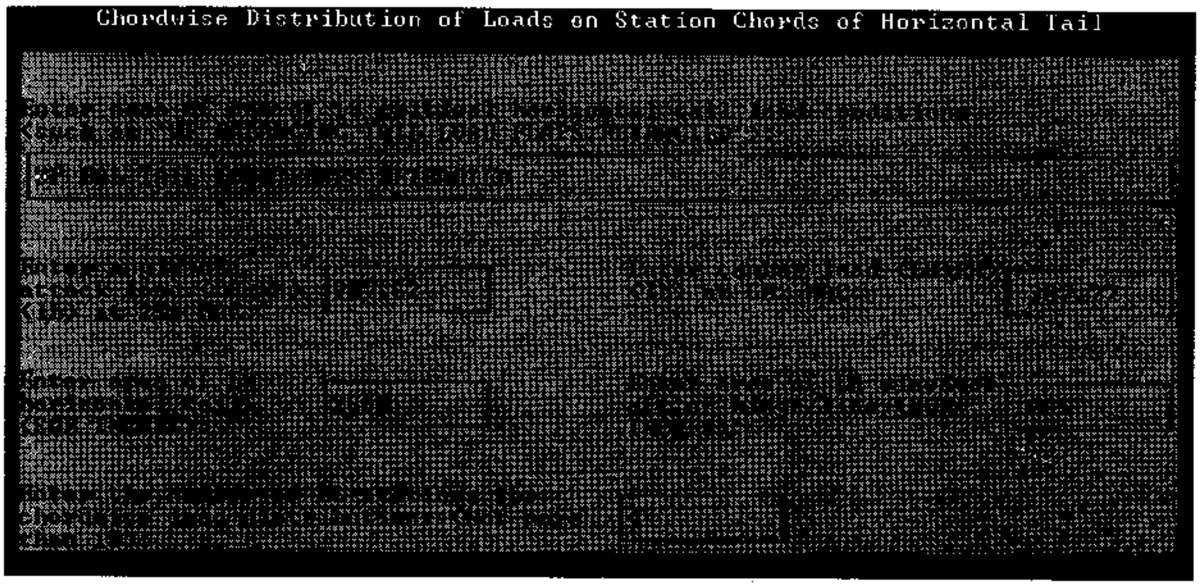

FIGURE 20.7 TAILDIST "CRITICAL HORIZONTAL LOAD DISTRIBUTED ON STATIONS" FIRST INPUT WINDOW

On Page2 and Page3 (if needed), the data for each butt line station is entered in inches. The data required is

- the butt line of the station,
- chord of horizontal tail at the butt line station,
- chord of elevator at the butt line station, and
- chord of elevator aft of the hinge line at the butt line station.

Only five locations can be entered on Page2. If you have more than five locations, you will need to use Page3 to enter the remaining locations.

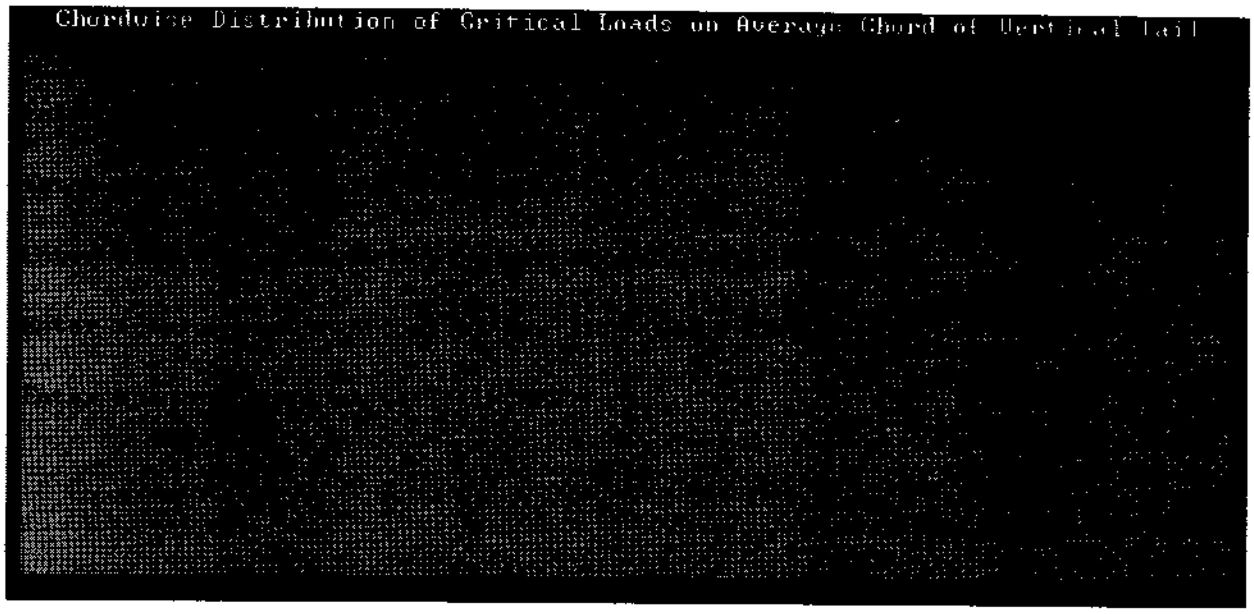

FIGURE 20.5 TAILDIST "FOUR CRITICAL VERTICAL LOADS" FIRST INPUT WINDOW

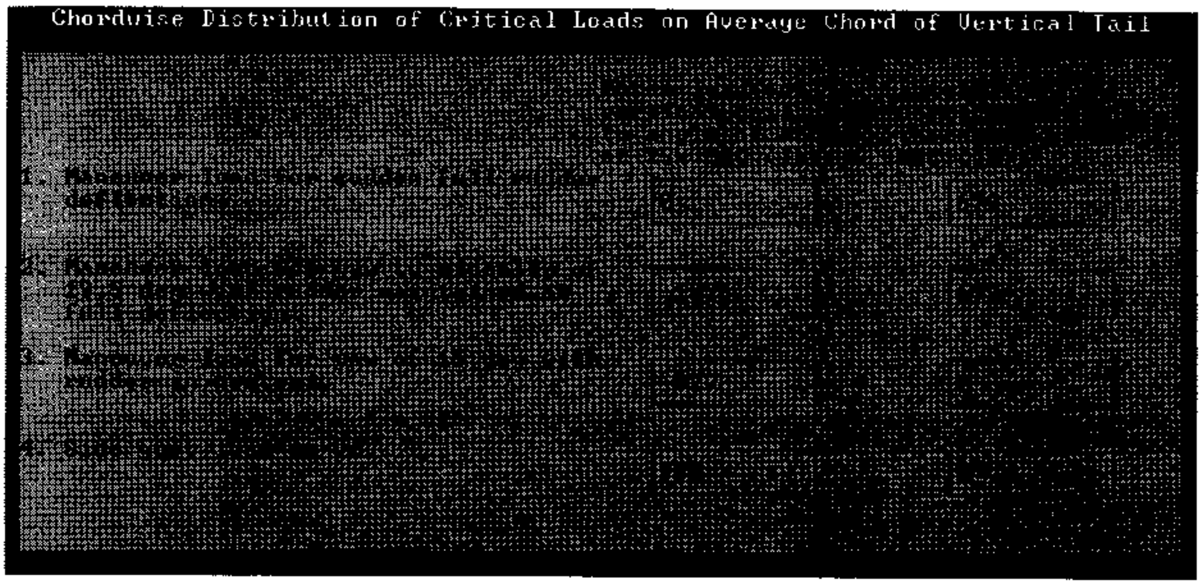

FIGURE 20.6 TAILDIST "FOUR CRITICAL VERTICAL LOADS" SECOND INPUT WINDOW

On Page2, the loads due to angle of attack at the 25% MAC and load due to camber at the 50% MAC are entered for four conditions. These conditions are

- maneuver load for sudden full rudder deflection,
- maneuver load for yaw to sideslip of 19.5° with rudder maintained at full deflection,
- maneuver load for yaw of 15° with rudder in neutral, and
- side gust load at V_C.

When entering the loads, you can use the *Tab* key to accept the data and move to the next cell. However, using the *Tab* key will move you across the columns, thereby entering all the data for a location before moving to the next location.

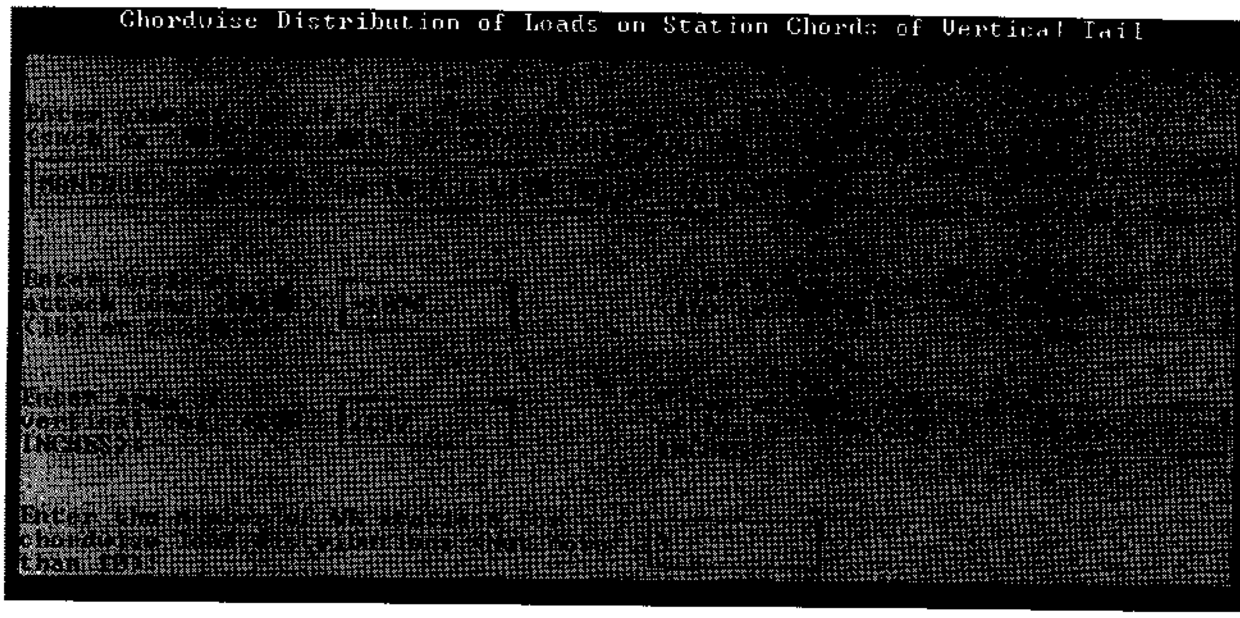

FIGURE 20.9 TAILDIST "CRITICAL VERTICAL LOAD DISTRIBUTED ON STATIONS" FIRST INPUT WINDOW

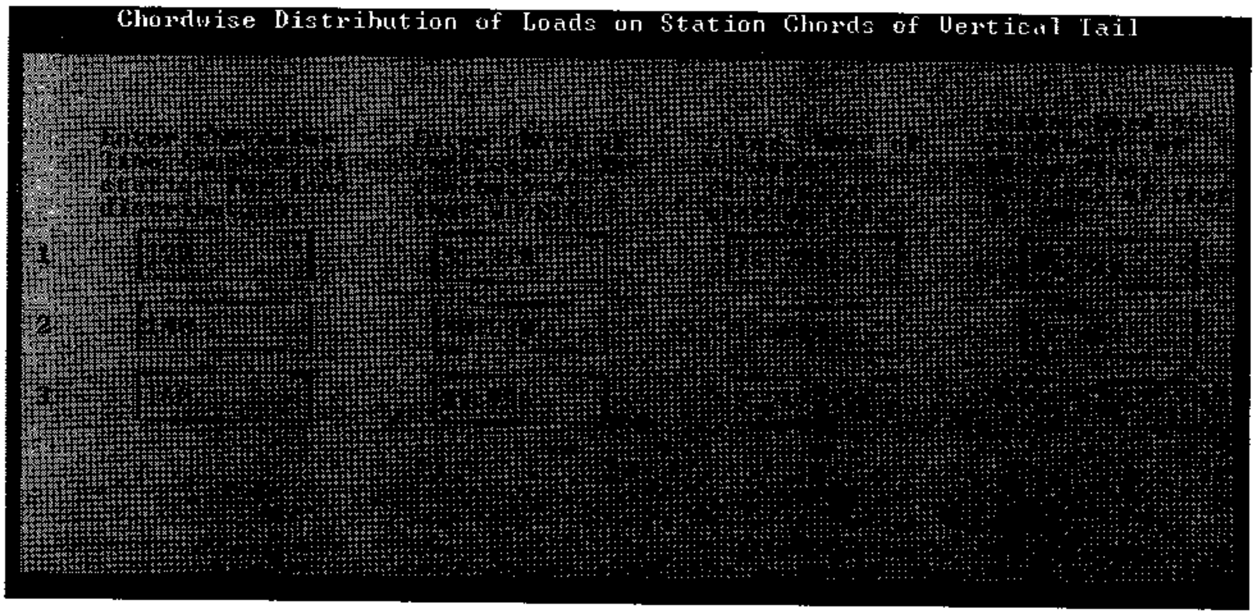

FIGURE 20.10 TAILDIST "CRITICAL VERTICAL LOAD DISTRIBUTED ON STATIONS" SECOND INPUT WINDOW

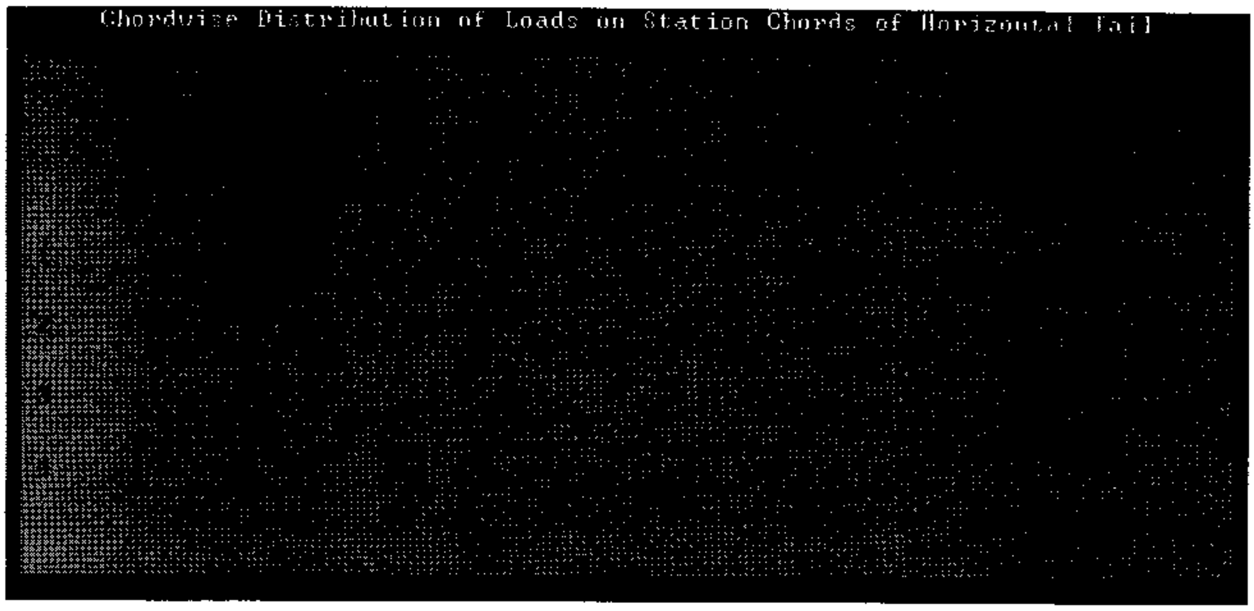

FIGURE 20.8 TAILDIST "CRITICAL HORIZONTAL LOAD DISTRIBUTED ON STATIONS" SECOND INPUT WINDOW

When entering the loads, you can use the *Tab* key to accept the data and move to the next cell. However, using the *Tab* key will move you across the columns, thereby entering all the data for a location before moving to the next location.

20.2.5 One Critical Vertical Tail Load Distributed on N Station Chords.

The input windows for this option are shown in figures 20.9 and 20.10. The input required includes the name of the load condition, the angle-of-attack load at the 25% MAC, the camber load at the 50% MAC, the area of the vertical tail, area of the rudder aft of the hinge line, and the number of water line stations for chordwise distribution. The loads are entered in pounds, and the areas are in square inches. The maximum number of water line stations is ten.

On Page2 and Page3 (if needed), the data for each water line station is entered. The data required is

- the water line of a station,
- chord of vertical tail at the water line station,
- chord of rudder at the water line station, and
- chord of rudder aft of the hinge line at the water line station.

Only five locations can be entered on Page2. If you have more than five locations, you will need to use Page3 to enter the remaining locations.

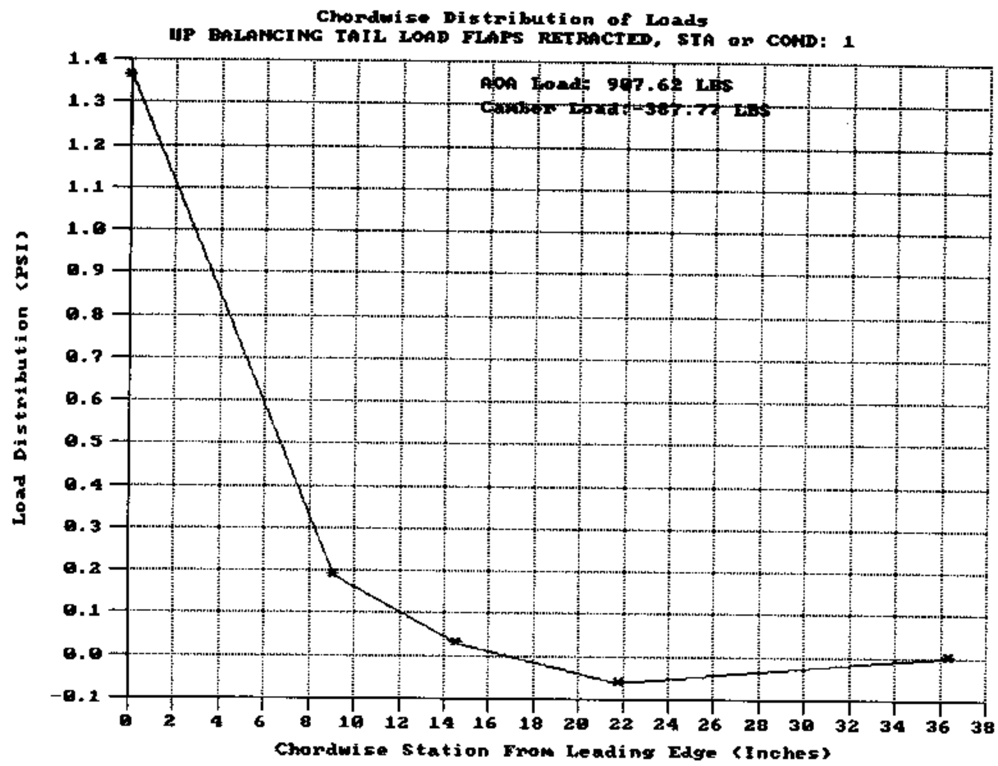

FIGURE 20.11 EXAMPLE OF RATIONAL TAIL LOADS GRAPH

20.2.6 Running the Analysis.

For all four analysis types, the analysis is run the same way. After all inputs are entered in the input windows, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. Currently, the second option does not work correctly and will give you error messages. Therefore, you should use the option *Save Output As* to save the output to a file, and then use Notepad (or similar program) to view and print the results. You can also print the output from DOS using the Print command.

20.3 TAILDIST OUTPUT.

TAILDIST produces two types of output files. The first type of output file comes from the first two options in the main menu, and the second type of output file comes from the last two options.

From the options for the load distribution on the average chord, the results of the TAILDIST analysis are the chordwise distribution of critical loads for each of the critical load conditions. For the horizontal tail, there are thirteen critical conditions; for the vertical tail, there are four critical conditions. The load distribution is given at five chordwise stations. In the output file, LT25 refers to the load due to angle of attack at the 25% MAC and LT50 refers to the load due to camber at the 50% MAC. This is an echo of your input.

The options for load distribution on N station chords results in the load distribution at the particular butt line or water line. For each station, the chordwise stations and loads are given.

20.4 GRAPHICS.

The separate graphics program FAR23 Plot can be used to draw the rational tail loads graphs. An example of one type of graph is shown in figure 20.11. The FAR23 Plot program is described in the appendix of reference 1.

To use the FAR23 Plot program, the output filenames must have the extension *.TLD*.

21.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window also includes three menu options: File, Notepad, and Color.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a printer or file. *Return to Main Menu* exits from TABLOADS and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input required for TABLOADS includes

- cruise speed V_C (KEAS),
- surface of interest (wing, horizontal tail, or vertical tail),
- the mean aerodynamic chord (MAC) for the tab (inches),
- the area of the tab (in^2),
- butt line of the MAC of the tab (inches),
- chord of wing (inches), and
- maximum deflection of the tab (degrees).

Depending on the surface that you select, the prompts on the input window will change to reflect your selections.

21.3.2 Running the Analysis.

After all inputs are entered in the input window, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

21.4 TABLOADS OUTPUT.

The output from TABLOADS includes the ratio of chord of tab to chord of airfoil, the tab load in pounds, and the tab pressure at the leading edge and trailing edge.

21. TAB LOADS.

21.1 TABLOADS DESCRIPTION.

The tab loads for the wing, horizontal tail, and vertical tail are determined in TABLOADS. The loads are calculated for full deflection at V_C at the shoulder on the structural limit diagram. This is where V_C is the highest in equivalent airspeed (KEAS) with the greatest Mach number.

21.2 FAR 23 REGULATIONS.

The requirements for the tabs are defined in FAR 23.409 and repeated here for convenience.

21.2.1 FAR 23.409 Tabs.

Control surface tabs must be designed for the most severe combination of airspeed and tab deflection likely to be obtained within the flight envelope for any usable loading condition.

21.3 RUNNING TABLOADS.

To run TABLOADS, select the button from the main menu window. The input window will be displayed as shown in figure 21.1.

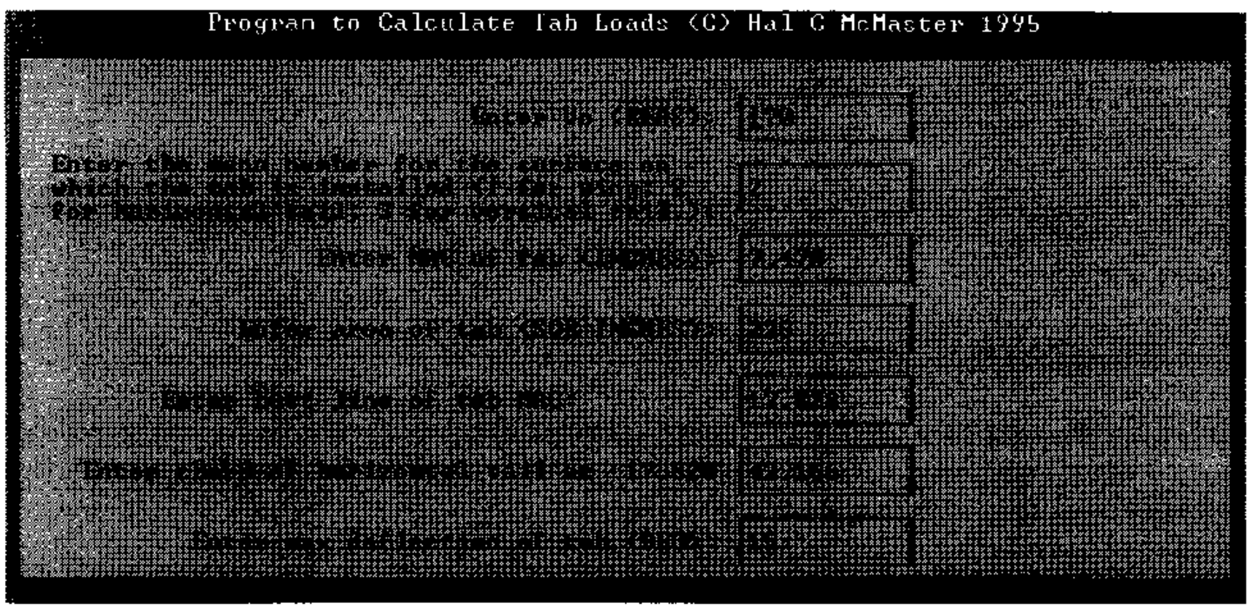

FIGURE 21.1 TABLOADS INPUT WINDOW

(2) At speeds between V_{MC} and V_C, the loads resulting from the disconnection of the engine compressor from the turbine or from loss of the turbine blades are considered to be ultimate loads.

(3) The time history of the thrust decay and drag buildup occurring as a result of the prescribed engine failures must be substantiated by test or other data applicable to the particular engine-propeller combination.

(4) The timing and magnitude of the probable pilot corrective action must be conservatively estimated, considering the characteristics of the particular engine-propeller-airplane combination.

b. Pilot corrective action may be assumed to be initiated at the time maximum yawing velocity is reached but not earlier than 2 seconds after the engine failure. The magnitude of the corrective action may be based on the limit pilot forces specified in FAR 23.397 except that lower forces may be assumed where it is shown by analysis or test that these forces can control the yaw and roll resulting from the prescribed engine failure conditions.

22.3 RUNNING ONENGOUT.

To run ONENGOUT, select the button from the main menu window. The first input window will be displayed as shown in figure 22.1.

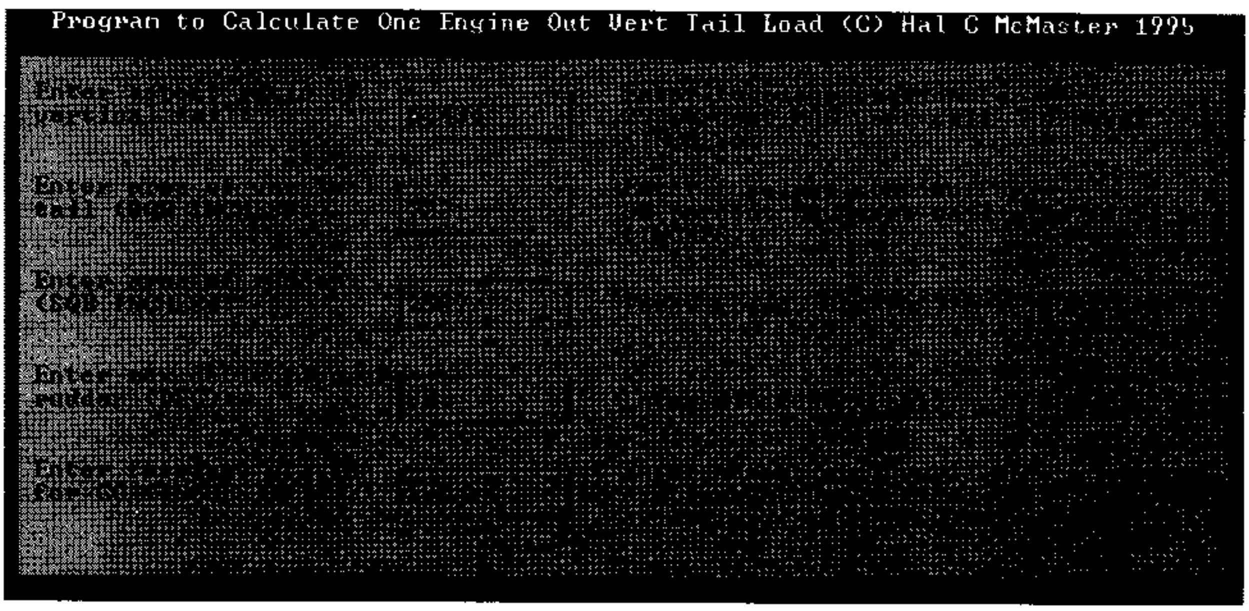

FIGURE 22.1 ONENGOUT FIRST INPUT WINDOW

22.3.1 Input Window.

The input window is displayed when the module starts and is used to specify the parameters for the analysis. This window includes five menu options: File, Notepad, Color, Page1, and Page2.

22. ONE ENGINE OUT LOADS.

22.1 ONENGOUT DESCRIPTION.

The loads for one-engine out are calculated with ONENGOUT. When one engine fails, the primary force acting on the airplane is an unbalanced moment about the vertical axis at the center of gravity of the airplane. The acceleration of the rotation of the airplane about the vertical axis at the c.g. is resisted by the mass moment of inertia of the airplane. As the airplane rotates, the vertical tail provides an aerodynamic force which also resists the unbalanced moment.

The net unbalanced moment and the inertia of the airplane determine the angular acceleration about the c.g. from the equation

$$\ddot{\psi} = {}^{torque}\!/_{I_{zz}}$$

where:

$\ddot{\psi}$ = angular acceleration about the c.g.
torque = net unbalanced moment
I_{zz} = mass moment of inertia about the vertical axis at c.g.

The angular velocity and the angle are calculated as

$$\dot{\psi}_2 = \dot{\psi}_1 + \ddot{\psi}\,\Delta T_{1-2}$$
$$\psi_2 = \psi_1 + \dot{\psi}_2 \Delta T_{1-2} + 0.5\ddot{\psi}\left(\Delta T_{1-2}\right)^2$$

where:

$\dot{\psi}$ = angular velocity
ψ = yaw angle
ΔT = increment of time

22.2 FAR 23 REGULATIONS.

The requirements for the unsymmetrical loads due to engine failure are defined in FAR 23.367 and repeated here for convenience.

22.2.1 FAR 23.367 Unsymmetrical Loads Due to Engine Failure.

a. Turbopropeller airplanes must be designed for the unsymmetrical loads resulting from the failure of the critical engine including the following conditions in combination with a single malfunction of the propeller drag limiting system, considering the probable pilot corrective action on the flight controls:

(1) At speeds between V_{MC} and V_D, the loads resulting from power failure because of fuel flow interruption are considered to be limit loads.

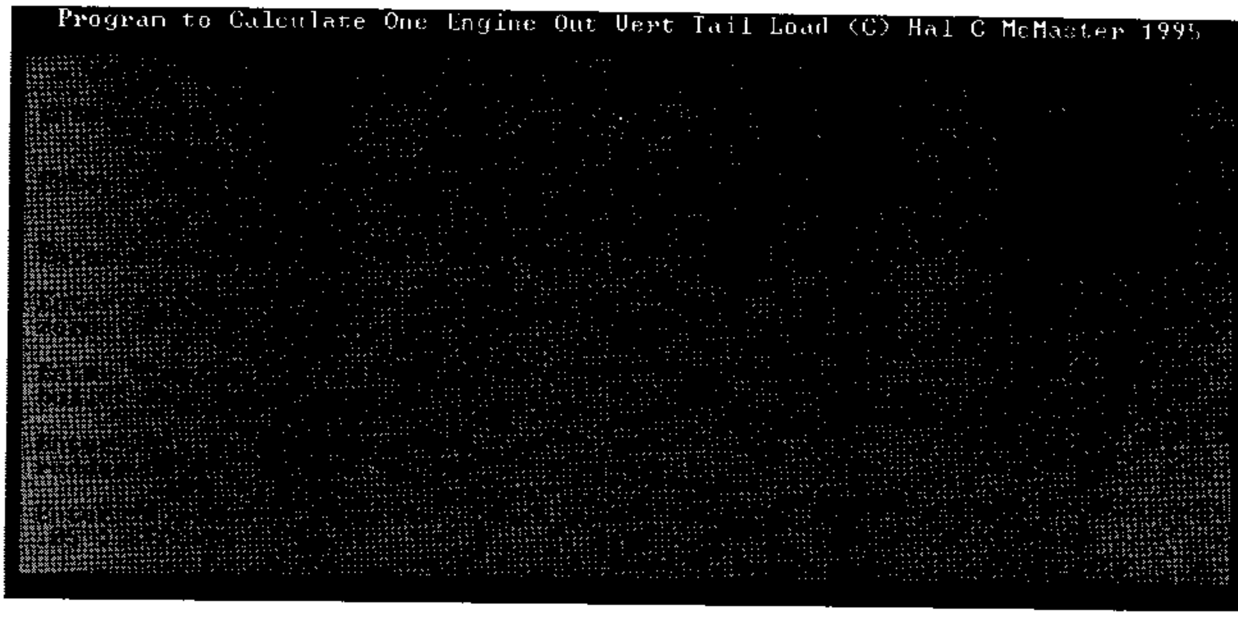

FIGURE 22.2 ONENGOUT SECOND INPUT WINDOW

22.3.2 Running the Analysis.

After all input are entered in the input windows, start the analysis by opening the File menu and selecting *Save Output As* or *Print Output*. Either selection will calculate the results and save the output to a file. The second option also prints the output.

For each speed such as V_C, V_D, and V_S, that you are interested in, you will need to run a separate analysis.

22.4 ONENGOUT OUTPUT.

The output of ONENGOUT includes the engine thrust in pounds, the windmill drag in pounds, maximum yawing velocity, and maximum tail load. The time history provides the data from zero time until recovery is complete in increments as specified. At each time increment, several parameters are printed. These parameters are defined in table 22.1.

In the time history, it is indicated when engine thrust has decayed to zero, when the windmill drag has built up to the maximum, when corrective action is initiated, and when recovery is complete.

The File menu is used to store and retrieve data from the program. The *New* command generates a new input window. *Open* allows you to retrieve a previously created and saved input file. *Save Input As* will allow the input data to be saved to a file. *Save Output As* will perform the calculations and allow the output data to be saved to a file. *Print Output* allows you to perform the calculations and print the output data to a printer or file. *Return to Main Menu* exits from ONENGOUT and returns to the FAR23 Loads Main Menu.

The Notepad option opens a Notepad program where you can review your input and output files.

The Color option allows you to change the color scheme displayed on your window.

The input for ONENGOUT is entered on two input windows as shown in figures 22.1 and 22.2. On Page1, the following data is entered:

- aspect ratio of the vertical tail,
- area of the vertical tail (in^2),
- area of the rudder (in^2),
- maximum deflection of the rudder (degrees),
- fuselage station of the c.g. (inches),
- fuselage station for the 25% MAC of the vertical tail (inches),
- fuselage station for the 50% MAC of the vertical tail (inches),
- speed (KEAS),
- altitude (feet), and
- moment of inertia of the airplane about vertical axis, I_{zz} (slug-ft^2).

The aspect ratio and area of the vertical tail and rudder come from WINGGEOM (section 6), and the moment of inertia is from WTONECG (section 4).

On the second input page, the following data is entered:

- butt line of the engine (inches),
- maximum horsepower of one engine,
- propeller diameter (feet),
- time at which thrust decays to zero (seconds),
- time at which windmill drag builds to maximum (seconds),
- time to develop full rudder deflection (seconds), and
- incremental time step (seconds) (suggested as 0.05).

You must run a separate analysis for each speed that you are interested in. This might include V_C, V_D, and V_S.

TABLE 22.1 DESCRIPTION OF VARIABLES USED IN THE OUTPUT FILE FROM ONENGOUT

VARIABLE NAME	DESCRIPTION
TIME	Time
THETA	Yaw angle
THETADOT	Angular velocity
THETA2DOT	Angular acceleration about the c.g.
LT25	Load at the 25% MAC
LT50	Load at the 50% MAC
LT	Total load
RUD DEFL	Rudder deflection (degrees)
MOMENT	Moment

23. REFERENCES.

1. McMaster, Hal C., "FAR 23 Loads," Aero Science Software, Wichita, KS, 1996.

2. Code of Federal Regulations, Title 14, Parts 1 to 59, Aeronautics Chapter I—Federal Aviation Administration, Subchapter C—Aircraft, Part 23—Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Category Airplanes, Subpart C—Structures, Revised as of January 1, 1994.

3. Pope, Alan, "Basic Wing and Airfoil Theory," McGraw-Hill Book Company, 1951.